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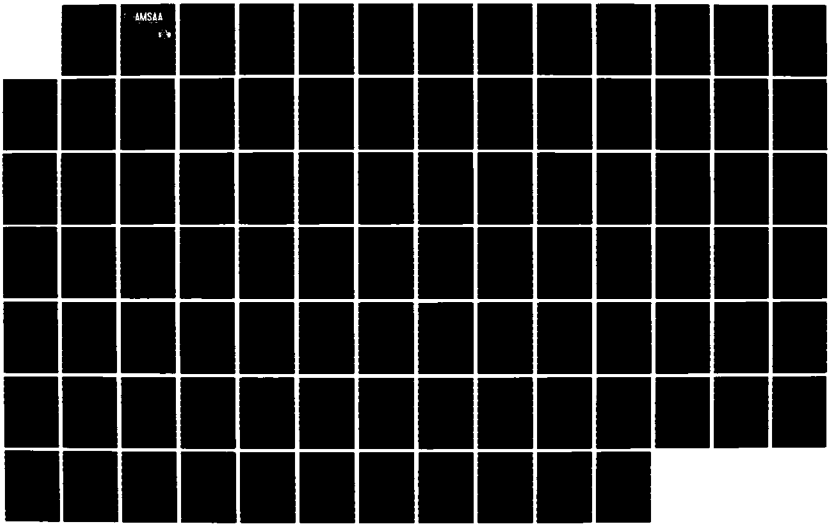

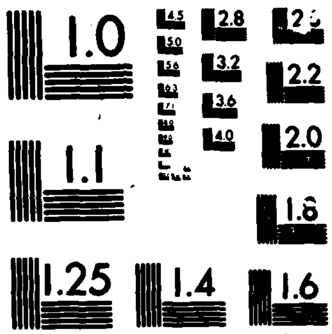
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LOGISTICS STUDIES OFFICE

PROJECT NUMBER 067

TECHNICAL REPORT

PRICE SCREENING METHODOLOGY

JANUARY 1986

U.S. ARMY MATERIEL SYSTEMS ANALYSIS ACTIVITY
LOGISTICS STUDIES OFFICE
FORT LEE, VIRGINIA 23801-6046

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PEER REVIEW

This report has been conscientiously reviewed by Messrs. Richard D. Abeyta, Operations Research Analyst, and David N. Dryden, Logistics Management specialist.

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Price; Production Lead Time (PLT); Federal Supply Classification (FSC).

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study determined the feasibility of developing price screens to flag invalid unit prices of Army Stock Fund (ASF) and Procurement Appropriation-Secondary (PA-2) items. Price bands were developed for three selected FSC groups using correlation and regression analysis. Production Lead Time (PLT) and size (cube) were used in the multiple regression equation to predict price. Although the degree of correlation was low, the price bands did improve the probability of flagging invalid prices in comparison to random sampling for high-priced items.

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SUMMARY

The Army Materiel Systems Analysis Activity (AMSAA), under the sponsorship of the Deputy Chief of Staff for Supply, Maintenance, and Transportation (SMT), HQ, US Army Materiel Command (AMC), has examined the feasibility of developing a system of price screens. These screens would flag those Army Stock Fund (ASF) and Procurement Appropriation-Secondary (PA-2) items in the Army Master Data File (AMDF) which have a high likelihood of having an erroneous price. Item parameters such as Production Lead Time (PLT) and size (weight and cube) were examined to find the best set of parameters that predict price for a specific group of items, such as a particular Federal Supply Classification (FSC). Price bands were then established to flag (identify) those items whose actual price differed by more than a predetermined amount from its predicted price. Items were grouped by FSC and by nomenclature. For the FSC groups, even though the correlation between item parameters and price was very small, the price bands did a better job at flagging invalid prices than would be expected if items were chosen at random. This was attributed to most of the invalid prices having high price values. Therefore, a generalized maximum price limit would have been just as effective. For the nomenclature groups, the absence of any correlation between price and the item parameters prohibited the development of price bands. Too many factors influence an item's price. This precludes the development of price bands based on the functional relationship between price and a given set of item parameters.

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PRICE SCREENING METHODOLOGY

Chapter 1. INTRODUCTION

1. Background.

a. In 1983, an Army Materiel Command (AMC) task force examined the Army's acquisition and pricing practices as part of the Spare Parts Review Initiative (SPRINT) effort. They found that contractor furnished unit price estimates for the spares of new systems entering the Army inventory are frequently inaccurate. These price estimates are entered by AMC into the Army Master Data File (AMDF). The Army uses these estimates for budgeting and requisitioning functions. The estimates remain in the AMDF until a representative buy establishes a new standard price. If no representative buy occurs, the initial price could remain in the AMDF forever.

b. In late 1983 through 1984, the Directorate for Supply, Maintenance, and Transportation, HQ AMC, conducted a price scrub of all Army Stock Fund (ASF) and Procurement Appropriation-Secondary (PA-2) items. The price review was made on provisioning items or items having no procurement history listed in the National Stock Number Master Data Record (NSNMDR). The prices of over 85,000 items were manually reviewed by the major subordinate commands (MSCs). Price changes were needed for about half of them. Most of the price changes involved increases or decreases of greater than 25 percent. This high percentage created concern about the quality of prices entering the AMDF as well as about current prices.

2. Objective. Determine the feasibility of developing price screens to flag invalid unit prices.

3. Limits and Scope. This study encompassed the AMC cataloging and supply management functions. ASF prices from selected Federal Supply Classification (FSC) classes were analyzed to satisfy the study objective. Three FSC and

three nomenclature categories were used in the study. Item parameters available in the Commodity Command Standard System (CCSS) were considered in the analysis.

4. Assumptions.

a. Prices scrubbed during the 1984 AMDF Price Scrub are now valid.

b. Production Lead Time (PLT) is reasonably constant between successive procurements.

5. Methodology.

a. A two-sided T-test was performed to compare the arithmetic means of unit price and PLT among FSC groups. This comparison was made to see whether the FSC groups consist of distinct groups of data and therefore require separate price bands.

b. Correlation analysis was used on an FSC or nomenclature group to find the highest degree of association between price and item parameters, such as PLT, weight, and cube. The impact of the type of buy (i.e., competitive vs sole source) was also examined. Regression analysis was then used to determine the best functional relationship between price and the significant parameters. Price bands were formed by placing confidence bands on the residual (predicted price - actual price) density distribution of the best fit regression surface.

c. For the price bands to be useful, they must be more effective than random sampling at finding invalid prices. The comparison was made by using a benefit-cost analysis where the effectiveness of the bands compared to random sampling was shown on a benefit vs cost graph (i.e., number of "predetermined" invalid prices found vs total number of prices reviewed). This graph was also used to select the optimum price band. The optimum price band provided the greatest improvement over random sampling of finding invalid prices.

6. Findings and Conclusions.

a. There are no item parameters that have high correlation to valid prices and low correlation to invalid prices. Therefore, correlation and regression analysis cannot effectively segregate invalid prices from valid prices.

b. The best regression surfaces were developed using the natural logarithm (ln) of price versus PLT, and ln cube. One-sided bands placed above the regression surface were more effective in finding invalid prices than was random sampling. Most invalid prices in the original price scrub had high price values. This indicates that flagging prices which breach a price limit selectively placed above the mean ln price would also capture a higher percentage of invalid prices than would random sampling.

c. For two of the three FSC groups, the one-sided upper limit price bands were 30 percent more effective than random sampling in flagging prices that were incorrect by more than 50 percent.

d. The 19-character nomenclature does not contain sufficient data to distinguish items within a nomenclature group or subgroup.

e. The parameters in computer-readable form available in the AMDF are not sufficient to provide a basis for screening prices.

7. Recommendations.

a. Since correlation and regression analysis cannot segregate invalid prices from valid prices, this is not a suitable approach for developing price bands.

b. Artificial-intelligence at its present level of technology is not a practical approach to a price screening procedure. As the field of artificial-intelligence matures, its application should be reinvestigated. However, an artificial-intelligence approach would require more detailed data than is presently available in the cataloging system.

c. Further research is needed in the area of price limits as a price screening tool. Price limits should be selected based on analytical rationale, but yet be simple to develop.

Chapter 2. DATA COLLECTION

1. Price Band Development.

a. The ability of price bands to represent the limits or bounds (at a specified confidence level) of the true price distribution as a function of the items' parameters is dependent upon the validity and accuracy of the data used to develop the bands. Three criteria were used to select Army-managed secondary items that were current, valid, and characteristic of items requiring price screens.

b. The selected subset of Army-managed secondary items was obtained from CCSS at each of the AMC major subordinate commands (MSC). The criteria were:

(1) Items funded by the Army Stock Fund (ASF): To ensure that unit prices in the sample were inflation-adjusted and representative of a current procurement unit price. ASF items are adjusted for inflation annually. PA-2 items are not.

(2) Items placed in the inventory during the past five years: To ensure that the sample contained recent provisioning items. Provisioning items are the most likely candidates for the application of price screens since the price bands should reflect unit prices of items influenced by current manufacturing technology.

(3) Items having at least two representative procurements: To add stability to the unit prices in the sample.

c. A data call was sent to the MSCs in June 1985. The data received for each item were: Routing Identifier Code (RIC), National Stock Number (NSN), Nomenclature, Materiel Category Structure Code (MATCAT), Unit Price, Production Lead Time (PLT), Unit Weight, Unit Cube, and Acquisition Method Reason Code

(AMRC). Table 1 contains the number of items which met the criteria in paragraph 1b above.

TABLE 1. MSC Data Call

MSC	# OF ITEMS
AMCCOM	7,183
CECOM	1,319
AVSCOM/TROSCOM	603
MICOM	3,756
TACOM	3,672
TOTAL:	16,533

2. Price Band Evaluation.

a. The price bands were evaluated for their effectiveness as a screening system to identify invalid prices by comparing the bands to a control group whose prices had been individually reviewed. AMC conducted an AMDF Price Scrub in 1984 where secondary item prices were individually reviewed at the major subordinate commands (MSC). The data was aggregated by the Catalog Data Activity (CDA).

b. Reviewed (initial) and scrubbed (resulting) price data was obtained from CDA on 91,721 ASF secondary items. These prices, predetermined as either valid or invalid (i.e., the initial price had been changed due to the scrub) were screened by the price bands. The screening determined the percentage of invalid prices among all prices flagged.

c. The data received from CDA were: RIC, NSN, Nomenclature, Reviewed (Old) Price, and Scrubbed (New) Price. Tallies of the AMDF Price Scrub data are in Table 2 below.

TABLE 2. AMDF Price Scrub Data

MSC	# OF ITEMS
AMCCOM	22,669
CECOM	15,074
AVSCOM/TROSCOM	19,068
MICOM	15,370
TACOM	19,540
TOTAL:	91,721

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Chapter 3. SELECTION OF FSC AND NOMENCLATURE GROUPS

1. Federal Supply Classifications (FSC).

a. The primary criterion in the selection of the three FSC groups was the most NSN matches; i.e., common items between the MSC (CCSS) data and the AMDF Price Scrub data. This control group data needed as many items as possible to evaluate and to optimize the price bands. The number of NSN matches for each selected FSC is shown in Table 3. The MSC data provided the item parameters and the AMDF Price Scrub provided the valid-invalid determination of the original price. The selection also considered that the FSCs contained items managed by each of the six MSCs.

TABLE 3. FSC Group Quantities

FSC CLASS	TITLE	# OF ITEMS		
		AMDF SCRUB	MSC	CONTROL GROUP*
1680	Misc Aircraft Accessories & Components	1246	280	151
3110	Bearings, Antifriction Unmounted	579	124	32
5310	Nuts & Washers	1477	285	46

*Number of Matches

b. An analysis of variance (ANOVA) was performed on the arithmetic means of price and PLT for five FSC groups. The groups were 1680: Misc Aircraft Accessories & Components, N=280; 3110: Bearings, Antifriction Unmounted, N=124; 5210: Hand Tools, Nonedged Nonpowered, N=205; 5310: Nuts & Washers, N=285; and

5962: Microcircuits, Electronic, N=162, where N is the number of items in each FSC group. On the basis of the test data it can be concluded with 90 percent confidence that there is significant difference between the five FSC groups. Therefore, it is reasonable to assume that the FSCs are unique and that price bands can be developed for each FSC.

2. Nomenclatures.

a. Nomenclature groups were chosen to (a) pick one group where available parameters; i.e., cube, weight, and production lead time (PLT), would be good predictors of price; (b) pick one group where factors not available to an automated system, such as materials, complexity, and quality of subcomponents, would outweigh cube, weight, and lead time as predictors; and (c) pick one group in between. The nomenclature groups also needed enough data for analysis. From the MSC tapes, files sorted by nomenclature were created. The same action was taken with the AMDF Price Scrub tape. From the nomenclature groups with the highest frequency of occurrence, "brackets" were selected as a simple item whose price should be closely related to PLT, cube, and/or weight. "Microcircuits" were selected as an item where factors other than PLT, cube, and weight should have dominant influence over price. Finally, "bearings" were selected as an item where PLT, cube, and weight were important, but complexity, machining tolerance, and materials also influence the price. Later in the study, nomenclature subgroups were selected from within two of the three groups to make the subgroups more homogeneous and therefore make them more likely to yield price prediction functions. Table 4 shows the number of items found for each group and subgroup in the AMDF Price Scrub file, the MSC file, and the control group (NSN matches).

TABLE 4. Nomenclature Group Quantities

GROUP	NOMENCLATURE	# OF ITEMS		
		AMDF SCRUB	MSC	CONTROL GROUP *
1	Bracket	2038	461	170
2	Bracket, Angle (Subgroup of 1)	425	114	38
3	Bearing	1056	198	89
4	Bearing, Ball, Annular (Subgroup of 3)	207	48	25
5	Bearing, Sleeve (Subgroup of 3)	229	48	20
6	Microcircuit	1349	219	152

*Number of Matches

b. Graphics techniques were used to determine whether items in one group were generally cheaper or more expensive than items in another group for similar cube and PLT. For example, for the comparison between brackets and bearings, the items were divided into ranges of unit cube. Within each range, graphs of scrubbed price versus PLT were produced, showing the data points and the least-squares straight lines for both brackets and bearings. Table 5 summarizes the results for brackets and bearings. Not surprisingly, microcircuits proved to be more expensive than angle brackets with equivalent unit cubes and production lead times. Comparisons of annular bearings and sleeve bearings were inconclusive because of the small sample sizes in the control set.

TABLE 5. Price Comparison of Brackets Versus Bearings

UNIT CUBE RANGE	HIGHEST PRICE GROUP*		EQUAL PRICE
	BRACKETS	BEARINGS	
.000 - .001	X		
.002 - .004	X		
.005 - .009	X		
.010 - .019			X
.020 - .049			X
.050 - .099	X		
.100 - .199		X	
.200 - .499		X	
.500 - 1.000	X		

*Based on equivalent production lead times

Chapter 4. PRICE BAND METHODOLOGY

1. The prices for an FSC group were best fitted to a multiple nonlinear regression equation. The price bands (or confidence bands) around the regression "surface" were developed using the price residuals. The residual is the difference between the actual price and the predicted price[1]; it is the distance between the actual price and the best fit regression surface. The spread or dispersion of the actual prices around the multiple dimension regression surface is shown as a distribution of the residuals in Figure 1. The density is greatest near the regression surface and diminishes as you move from it.

2. The residual density distribution in Figure 1 is useful in the development of price bands. If the density distribution is normal, it can be transformed into a standardized normal distribution with mean = 0 and standard deviation = 1. See Figure 2. The distance from the mean is called the standardized normal variate, computed as:

$$z = \frac{x - \mu}{\sigma}$$

where

x = residual.

μ = mean of residual distribution.

σ = standard deviation of residual distribution.

[1]The term "price" in reference to the regression equation or surface in this report is referring to the "ln price" term in the regression equation.

Confidence intervals representing price bands can then be easily developed. For example, to develop 80 percent confidence intervals, 80 percent of the area under the standardized normal distribution lies between $z = \pm 1.28$.

Since

$$x = \mu + z\sigma$$

The upper and lower price band limits are

$$x_u = \mu + 1.28\sigma$$

$$x_l = \mu - 1.28\sigma$$

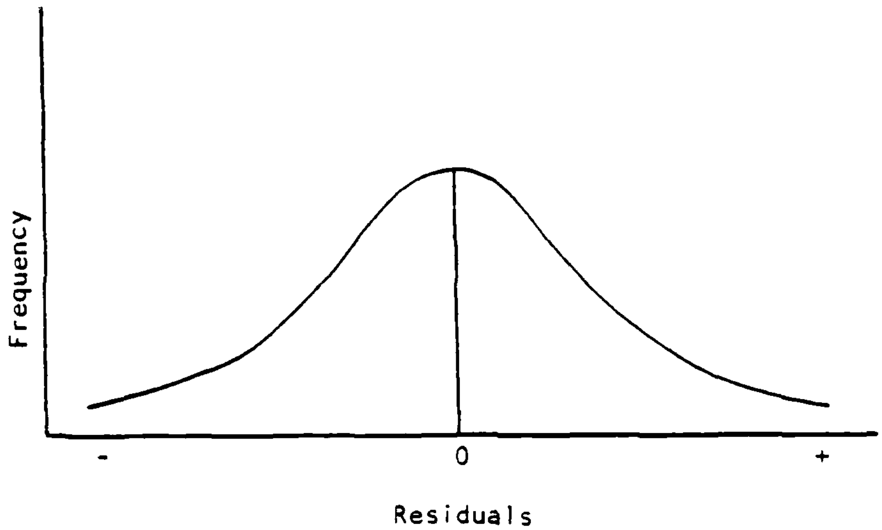

Figure 1. Price Residual Dispersion

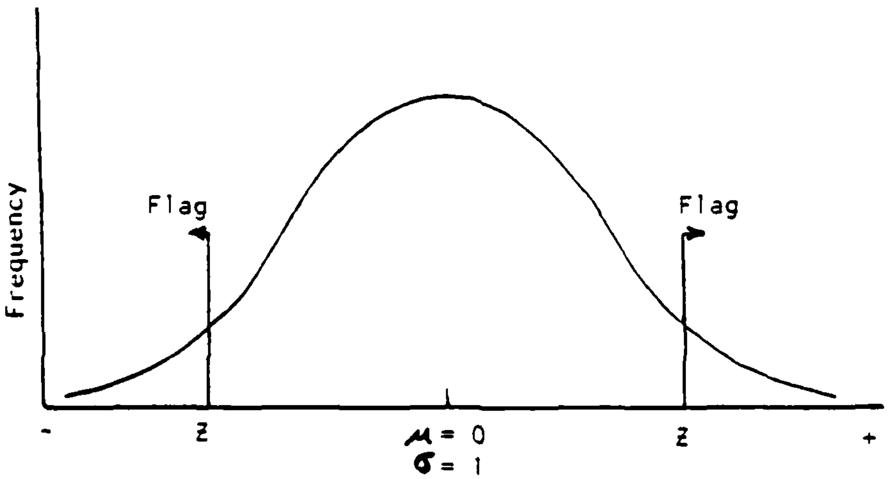

Figure 2. Standardized Normal Distribution

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Chapter 5. EVALUATION AND OPTIMIZATION OF PRICE BAND EFFECTIVENESS

1. Comparison of Original Prices to Reviewed Prices.

a. The unit prices reviewed during the AMDF Price Scrub in 1984 provided a control set of data used to evaluate the price bands. This data provided tallies of the number of valid and invalid prices flagged and not flagged for a given price band. From this data, the effectiveness of the price bands could be determined and a benefit-cost analysis could be performed to determine the optimum band.

b. To utilize the AMDF Price Scrub data in evaluating the price bands, each original price (i.e., the reviewed price) had to be designated as either valid or invalid.

(1) This was done by constructing a histogram of the ratios of the revised (scrubbed) price to the original price. For example, a ratio of 1.25 indicates that the revised price of the item is 25% higher than the original price. The magnitude of the differences between the revised and original prices can be seen on a histogram. Appendix A contains a histogram of revised price/original price ratios for a sample of 10 FSCs from the AMDF Price Scrub. The ten FSCs comprise 7,713 reviewed prices.

(2) Next, a boundary was placed symetrically around the 1.00 ratio on the histogram. An item whose ratio fell inside the boundary was designated as having a valid price. The size of the boundary widths affect the proportion of the items in the group that are considered to have valid prices. This in turn affects the evaluation of the price bands. Some degree of variation between the original and revised prices must be considered to account for error in estimating a reasonable price during the AMDF Price Scrub. Since the

regression surface and the price bands only show a general relationship between price and the item parameters, it is not reasonable to expect the bands to flag prices which are only off by a small percentage, such as + or - two percent.

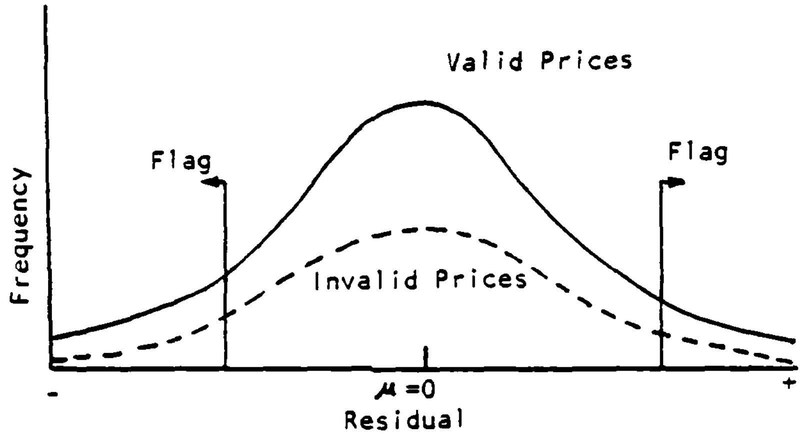
(3) Of the 7,713 prices in the ten FSC groups selected for the histogram, 50.6 percent of the items reviewed had no price change; i.e., the ratio of revised to original price was equal to one. Two "valid" boundary widths (of ± 10 and 50 percent) were chosen to evaluate the price bands. These two criteria measured the price bands' effectiveness to flag any invalid prices (applying the ± 10 percent range) and also the significantly incorrect prices (applying the ± 50 percent range). The histogram contained 39.7 and 26.3 percent invalid prices based on the ± 10 and 50 percent boundary criteria, respectively.

2. Comparison of Valid vs Invalid Price Density Distributions.

a. The valid-invalid price designations of the control group were used to evaluate and to optimize the effectiveness of the price bands. By placing the best fit multiple nonlinear regression surface through the control data, residual density distributions of the valid and invalid prices were determined.

b. The use of price bands to segregate the invalid prices from the valid prices was dependent on the underlying contours of the valid and invalid residual density distributions. Similarly shaped density distributions defeat the concept, with results no better than random sampling. This is illustrated in Figure 3a. If the shape of the density distributions are relatively inverse of each other, the feasibility of isolating regions with a high ratio of invalid to valid prices is supported. See Figure 3b.

a. Similar Contours



b. Inverse Contours

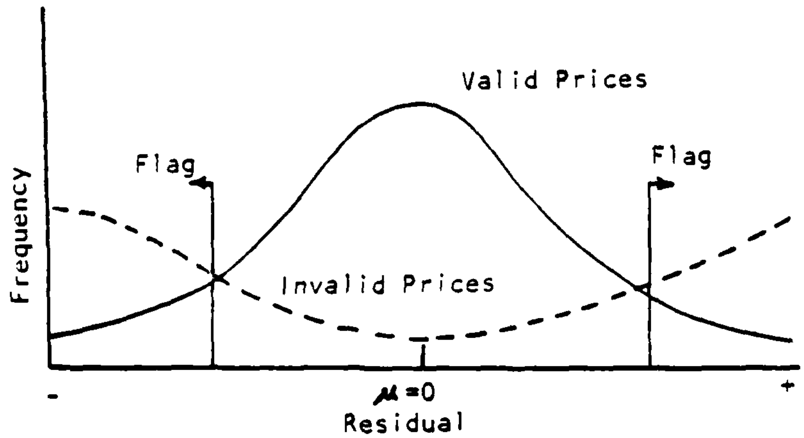


Figure 3. Contours of the Price Residual Density Distributions

3. <u>Optimization of Price Bands</u>.

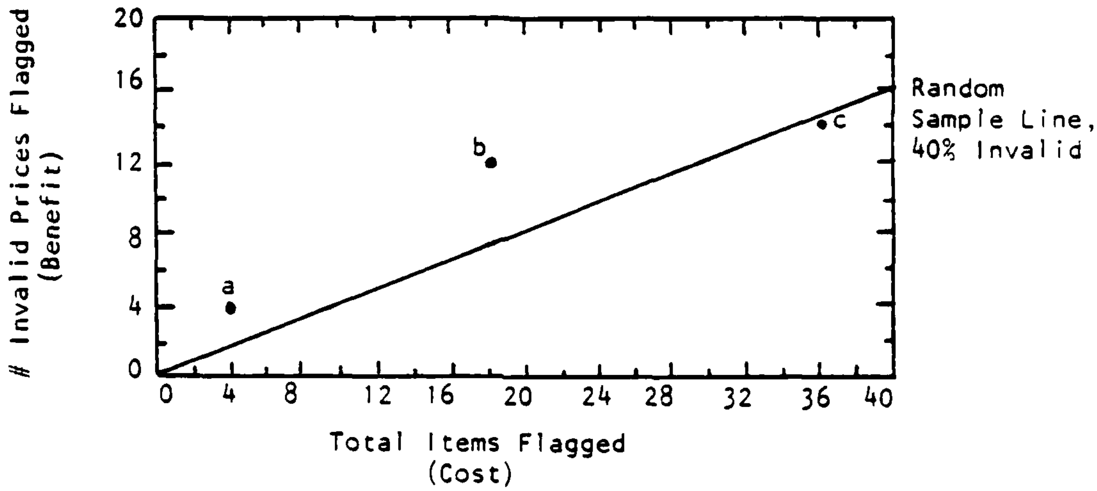
a. A benefit-cost analysis was used to find the optimun price bands. The optimum bands give the best chance of capturing invalid prices over the expected results from random sampling. The percentage of invalid prices flagged using random sampling would equal the percentage of invalid prices in the population. The price bands are meant to increase the probability of flagging invalid prices.

b. The number of invalid prices found is dependent on the total number of prices flagged and the efficiency of the bands; i.e., the percentage invalid of those flagged. The more prices that are flagged, the more invalid prices that will be found. This is illustrated in Figure 4a which shows the benefit-cost effects of three different price bands. The benefit (number of invalid prices found) is related to a cost (total number of prices flagged and reviewed). The diagonal line shows the expected outcome of random sampling. In this example, the underlying percentage of invalid prices in the population is 40%. Therefore, from a random sample of 20 prices, we would expect to find eight invalid prices (.40 x 20 = 8).

c. By using different bands on the valid and invalid price density distributions of the control data (see Figure 4b), the benefit-cost effects on Figure 4a can be developed. In this example, a wide band would flag few prices. A high percentage of those flagged would be invalid. The cost increases as the band narrows. The optimum band has its benefit-cost point farthest above the random sample line. This is band "b" where 67 percent (12 of 18) of those flagged are invalid.

d. The price band does not necessarily have to be two-sided. A one-sided band; i.e., an upper or lower limit on the density distributions may be more appropriate, such as where a high percentage of invalid prices fell on one side of the regression surface.

a. Benefit-Cost Analysis



b. Varying Band Widths

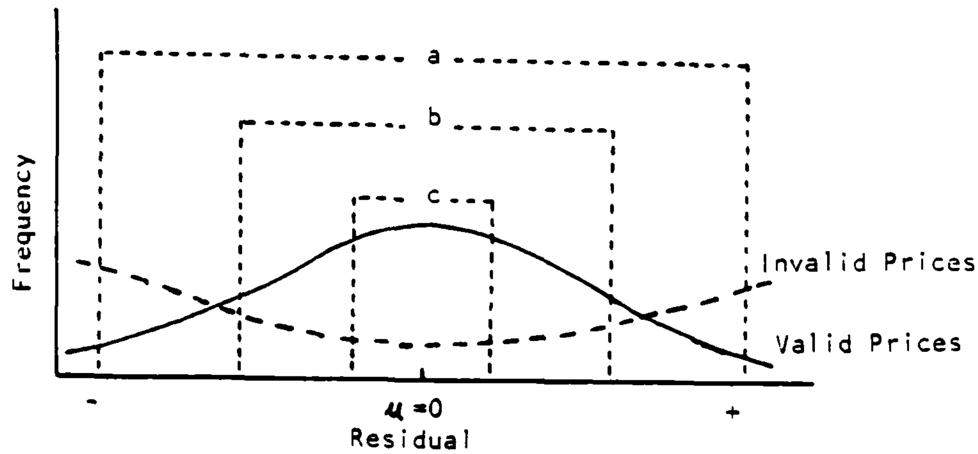


Figure 4. Optimization of Price Bands

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Chapter 6. FEDERAL SUPPLY CLASSIFICATION (FSC) PRICE BANDS

1. FSC 1680, Miscellaneous Aircraft Accessories and Components.

a. The relationships between price, PLT, weight, and cube were analyzed by applying regression analysis on all possible combinations of the variables. The data were subgrouped by the type of buy; i.e., competitive vs sole source, to observe their effects on the relationships. The data distributions for price, weight, and cube were highly skewed towards small values. These variables were transformed by taking their natural logarithms (ln). This transformation caused the data to appear more linear when plotted as log-log paper. Therefore, least squares minimization can be used to fit a straight line to the transformed data. Selected scatter plots are contained in Appendix B (pages 53 thru 55).

(1) The best results from single and multiple nonlinear regression are contained in Table 6. The "all data" type buy included the data comprising both the "competitive" and "sole source" subgroups. The "sole source" data had much higher correlation than the "competitive" data. The best single nonlinear regression was obtained using PLT as the independent variable. A hypothesis test, $H_0:R^2=0$ and $H_1:R^2\neq0$, indicated that at 90 percent confidence, H_0 can be rejected; i.e., there is correlation between ln price and PLT. Significant improvement in the correlation was obtained by adding ln cube as the second independent variable. This gave an $R^2=.379$, meaning that 37.9 percent of the variation in ln price can be attributed to PLT and ln cube. The remaining price variation is unexplained and can be attributed to such factors as procurement quantities, sources (e.g., prime contractor, manufacturer, or vendor), priority delivery schedules, obsolete or out of production items, contracting methods (e.g., small purchase, formal advertising, negotiation, unprice order),

and changes in technical data since the last procurement. The correlation (R=.57) between ln cube and ln weight was high enough to indicate multicollinearity. Therefore, ln weight was not added to the regression equation.

(2) The multiple nonlinear regression equation using all the data (both competitive and sole source) was selected over the "sole source" equation because the amount of improvement in correlation; i.e., R, is insignificant. A hypothesis test, $H_0:R^2=0$ and $H_1:R^2\neq 0$, on the "all data" equation indicated that at 90 percent confidence, H_0 can be rejected. There is correlation between ln price and the independent variables PLT and ln cube. A hypothesis test, $H_0:b_i=0$, $H_1:b_i\neq 0$, on the regression coefficients, b_i, rejected the null hypothesis at 90 percent confidence. Therefore, the coefficients are not zero and affect the value of ln price. The regression surface intercepts the price axis at $11.13 (ln price = 2.47).

TABLE 6. Correlation and Regression Results for FSC 1680

INDEPENDENT VARIABLES	TYPE BUY	N	R	R^2
PLT	Competitive	20	.23	.05
	Sole Source	73	.56	.31
	All data	93	.54	.29
PLT, ln cube	Competitive	20	.39	.15
	Sole Source	73	.619	.383
	All data	93	.616	.379

Type Buy	Best Equation
All data	ln Price = .18(PLT) + .31(ln cube) + 2.47

b. The density distributions about the regression surface for the control group data are shown in Figures 5 and 6. Referring back to Figure 3, the shape of the invalid versus the valid density distributions will indicate the feasibility of flagging a higher percentage of invalid prices in comparison to random sampling. Using random sampling, 56 and 26 percent of the flagged prices would be invalid based on the ± 10 and ± 50 percent valid price designation criteria. The distributions for both criteria look similar. A T-test to compare the distribution means and variances between the invalid and valid distributions showed that at 90 percent confidence, we can not say that the means and variances are significantly different.

c. The optimum price bands for the ± 10 percent criterion was a one-sided band of the top 45 percent. This band would be on the left side; i.e., the high price side, of the distributions in Figures 5 and 6, and it would flag the top 45 percentile of the price residuals. These are the items whose prices are the highest above the regression surface. This 45 percent top band captured 63 percent (52 of 83) invalid prices of those flagged for a 13 percent improvement over random sampling. The best results for the ± 50 percent criterion were obtained with a 75 percent two-sided band. This captured 35 percent (14 of 40 flagged) of the invalid prices for a 35% improvement over random sampling. Table 9 contains a summary of these results along with the results for FSCs 3110 and 5310 below.

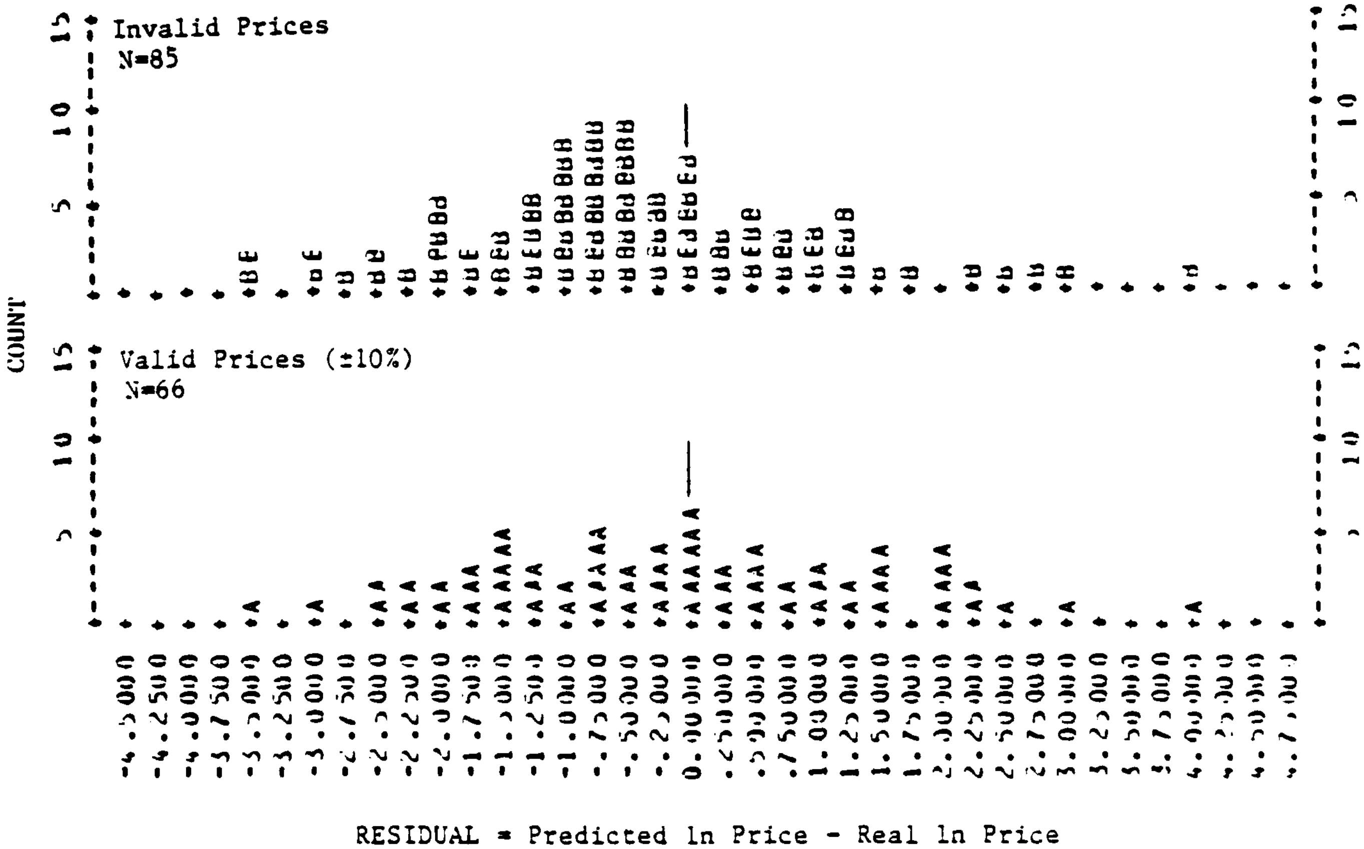


Figure 5. Valid (±10%) & Invalid Residual Density Distributions, FSC 1680

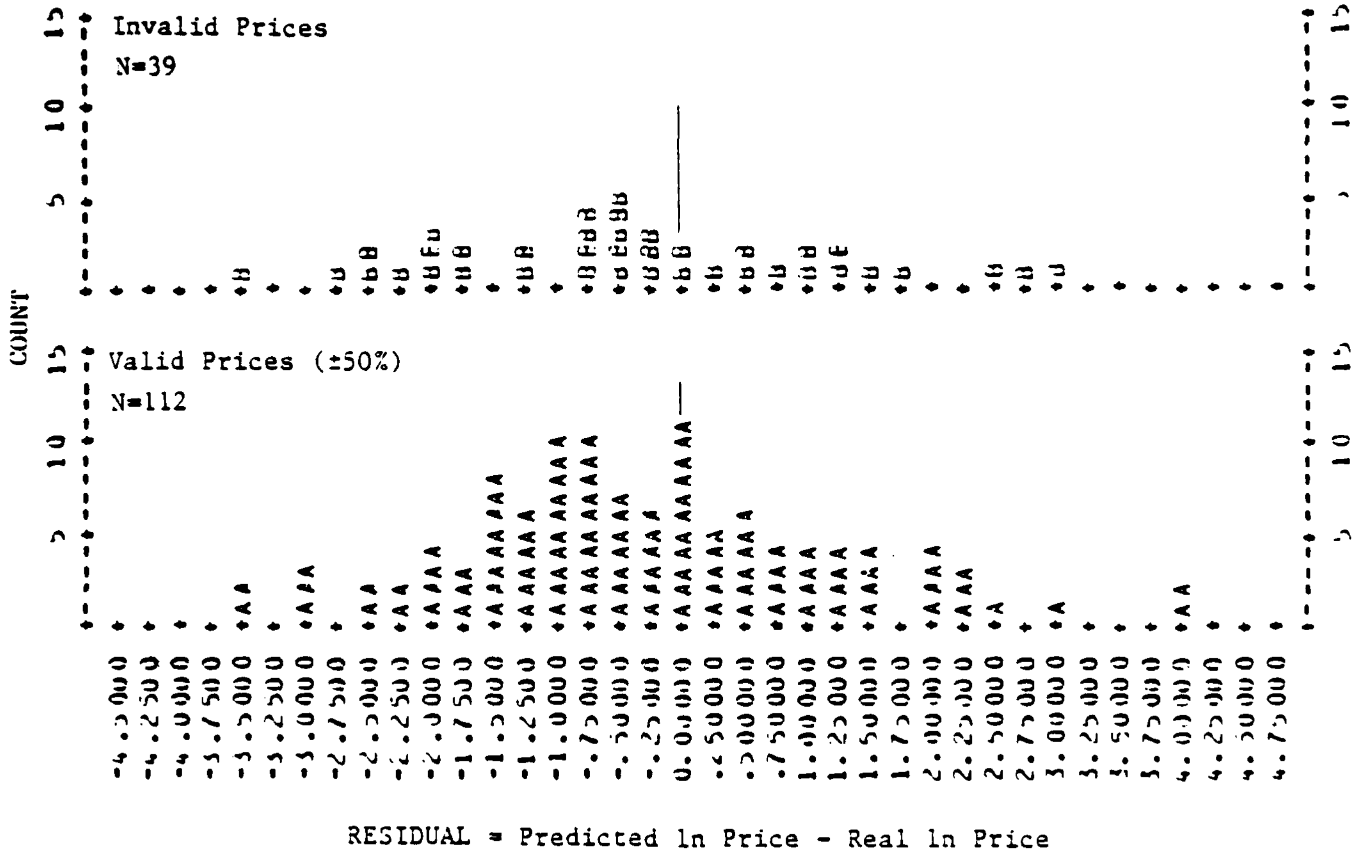


Figure 6. Valid (±50%) & Invalid Residual Density Distributions, FSC 1680

2. <u>FSC 3110, Bearing, Antifriction Unmounted.</u>

a. FSC 3110 produced the highest correlation results of the three FSC groups examined in this report. Selected scatter plots are in Appendix B (pages 56 thru 58). The results are summarized in Table 7. The relationship of ln price to PLT and ln cube had an R=.71 (R^2=.50). One half of the variation in ln price is attributed to PLT and ln cube. Hypotheseis tests on R^2 and the regression coefficients showed that at 90 percent confidence, R^2 and the regression coefficients are not equal to zero. The best single regression results were obtained using ln cube. The "competitive" data had higher correlation than the "sole source" data. Ln weight was not added to the multiple nonlinear regression equation because of its multicollinearity to ln cube (R=.65). The best fit regression surface is shown in Appendix B, p. 58. The regression surface intercepts the price axis at $2.72 (ln price = 1.00).

TABLE 7. Correlation and Regression Results for FSC 3110

INDEPENDENT VARIABLES	TYPE BUY	N	R	R^2
ln Cube	Competitive	26	.72	.52
	Sole Source	64	.663	.44
	All data	90	.668	.45
PLT, ln Cube	Competitive	26	.78	.61
	Sole Source	64	.67	.45
	All data	90	.71	.50

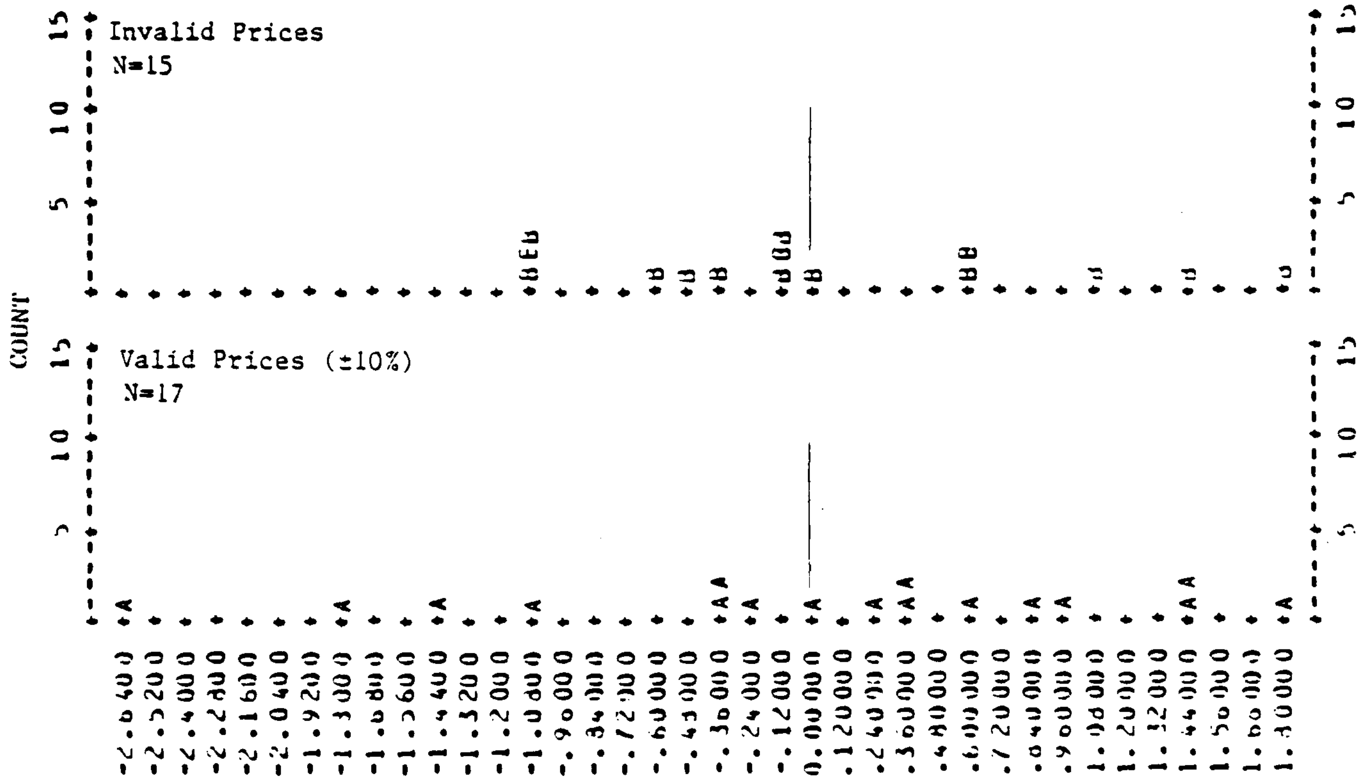
Type Buy	Best Equation
All data	ln Price = .07(PLT) + .84 (ln cube) + 1.00

b. The density distributions about the regression surface for the control group data are shown in Figures 7 and 8. Forty-five percent of the prices were invalid in the control group based on the ±10 percent criterion. Using the ±50 percent criteria, 33 percent were invalid. Comparing the shapes of the invalid and valid distributions is difficult due to insufficient data. A T-test to compare the distribution means and variances between the invalid and valid distributions was performed. At 90% confidence, we cannot say that the means and variances are significantly different.

c. A 40 percent top band produced the highest percentage of invalid prices of those flagged. Based on the ±10 percent criterion, the 40 percent top band captured 56 percent (5 of 9) invalid prices of those flagged compared to the expected 45 percent from random sampling. This is a 24 percent improvement. For the ±50 percent criterion, the 40 percent top band (4 of 9 for 44 percent invalid) was 33 percent better than the expected results from random sampling (33 percent invalid). The results are summarized in Table 9. However, the small size (N=32) of the control group prohibits strong conclusions to be made from these results.

3. <u>FSC 5310, Nuts and Washers</u>.

a. The best correlation to price was obtained using the parameters PLT and cube. See Appendix B for scatter plots (p. 59 thru 61). Table 3 summarizes the best results from the correlation and regression analyses. Single nonlinear regression produced poor results. Similar to the FSC 1680 group, the "sole source" data had much higher correlation than the "competitive" data. The correlation between ln cube and ln weight was high enough (R=.57) to indicate multicollinearity. The addition of ln cube in the regression analysis improved the results. Again, the "sole source" subgroup showed signs of some correlation



RESIDUAL = Predicted ln Price - Real ln Price

Figure 7. Valid (±10%) & Invalid Residual Density Distributions, FSC 3110

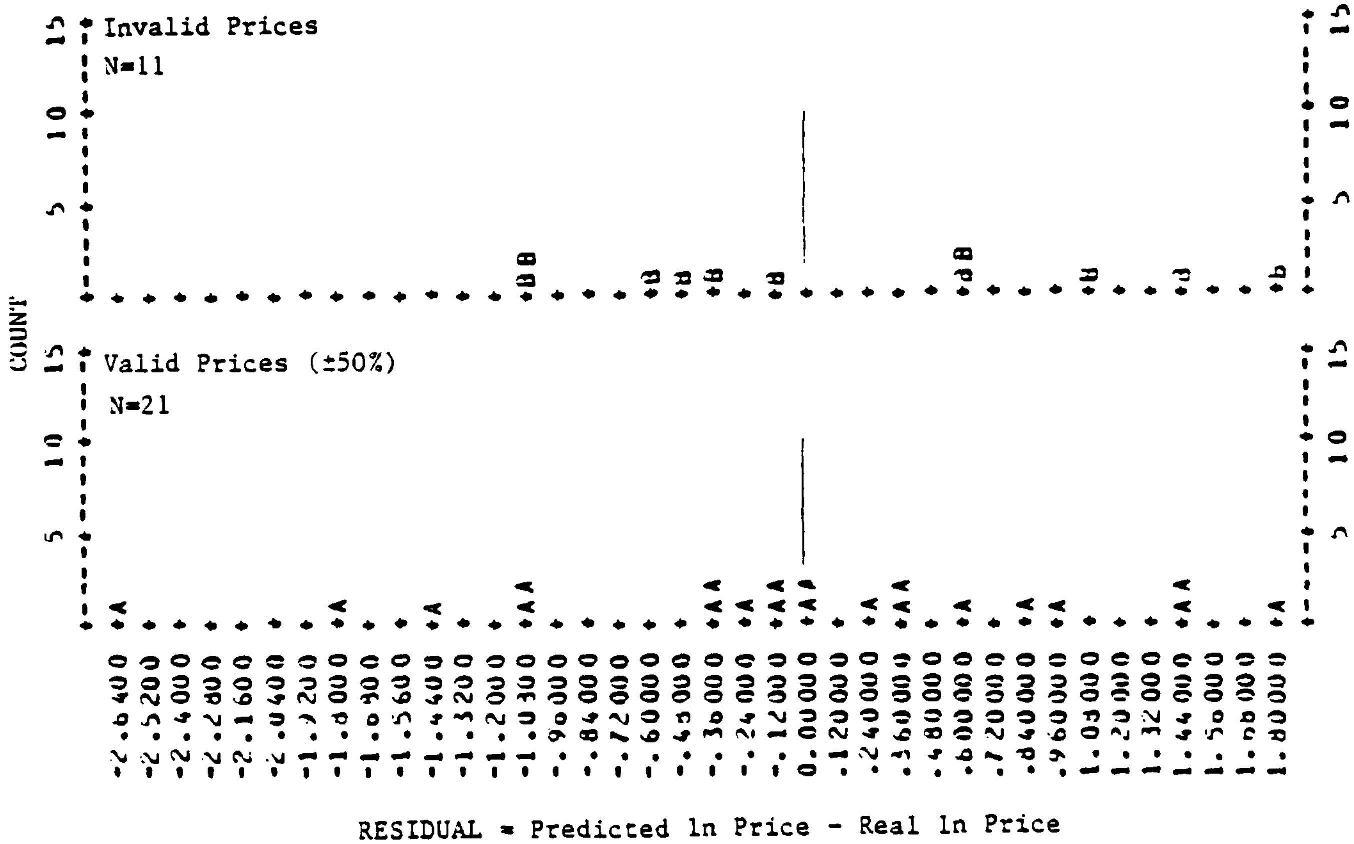


Figure 8. Valid (±50%) & Invalid Residual Density Distributions, FSC 3110

while the "competitive" subgroup did not. Hypothesis tests showed that at 90% confidence, we can say that R^2 is not zero and that the PLT and ln cube regression coefficients are not zero. Appendix B, p. 61, shows the best fit regression surface. The regression equations developed from all the data and from only the sole source data are similar. The difference between the price axis intercepts is only 86 cents (exp(.36)-exp(-.56)) Therefore, the two regression surfaces are very close to each other.

TABLE 8. Correlation and Regression Results for FSC 5310

INDEPENDENT VARIABLES	TYPE BUY	N	R	R^2
PLT	Competitive	74	.01	.00
	Sole Source	51	.40	.16
	All data	125	.17	.03
PLT, ln Cube	Competitive	74	.19	.04
	Sole Source	51	.51	.26
	All data	125	.28	.08

Type Buy	Best Equations
Sole Source	ln Price = .13(PLT) + .50 (ln Cube) - .56
All data	ln Price = .07(PLT) + .39 (ln Cube) + .36

Price bands were developed using the "sole source" equation and evaluated using only the sole source data in the control group and all the control group data. Price bands were also developed using the "all data" equation. Similar results were obtained in each case. This is due to the similiarity between the two regression surfaces, implying that the degree of correlation; i.e., the magnitude of R, is not an important factor in the evaluation or test of validity of the price bands. We are interested in flagging those items that fall in the outer

regions of the three-dimensional ln price vs PLT and ln cube scatter plot. The exact location and slant of the regression surface and the price band is not important.

b. The density distributions about the regression surface for the control group data is shown in Figures 9 and 10. For both the ±10 percent and ±50 percent criteria, the invalid price distribution was further to the left than the valid price distributions. The left side represents the area above the regression surface; i.e., the high prices. The distributions in Figures 9 and 10 reveal that one-sided bands on the left; i.e., top bands, would be effective in flagging invalid prices. Although the valid and invalid control group distributions appear to be from different distributions, a T-test to compare the two distributions showed that at 90 percent confidence, we cannot say that the distributions' means and variances are significantly different. This is due to the small size of the distributions.

c. The optimum price bands for both ±10 percent and the ±50 percent criteria is a 45 percent top band. The underlying percentage of invalid prices in the control group was 63 and 54 percent for the ±10 and ±50 percent criteria, respectively. The 45 percent top band captured 81 percent (17 of 21) invalid prices of those flagged at the ±10 percent criterion, a 29 percent improvement over random sampling. For the ±50 percent criterion, 71 percent (15 of 21) of those flagged were invalid, a 31 percent improvement. See Table 9 for a summary of these results.

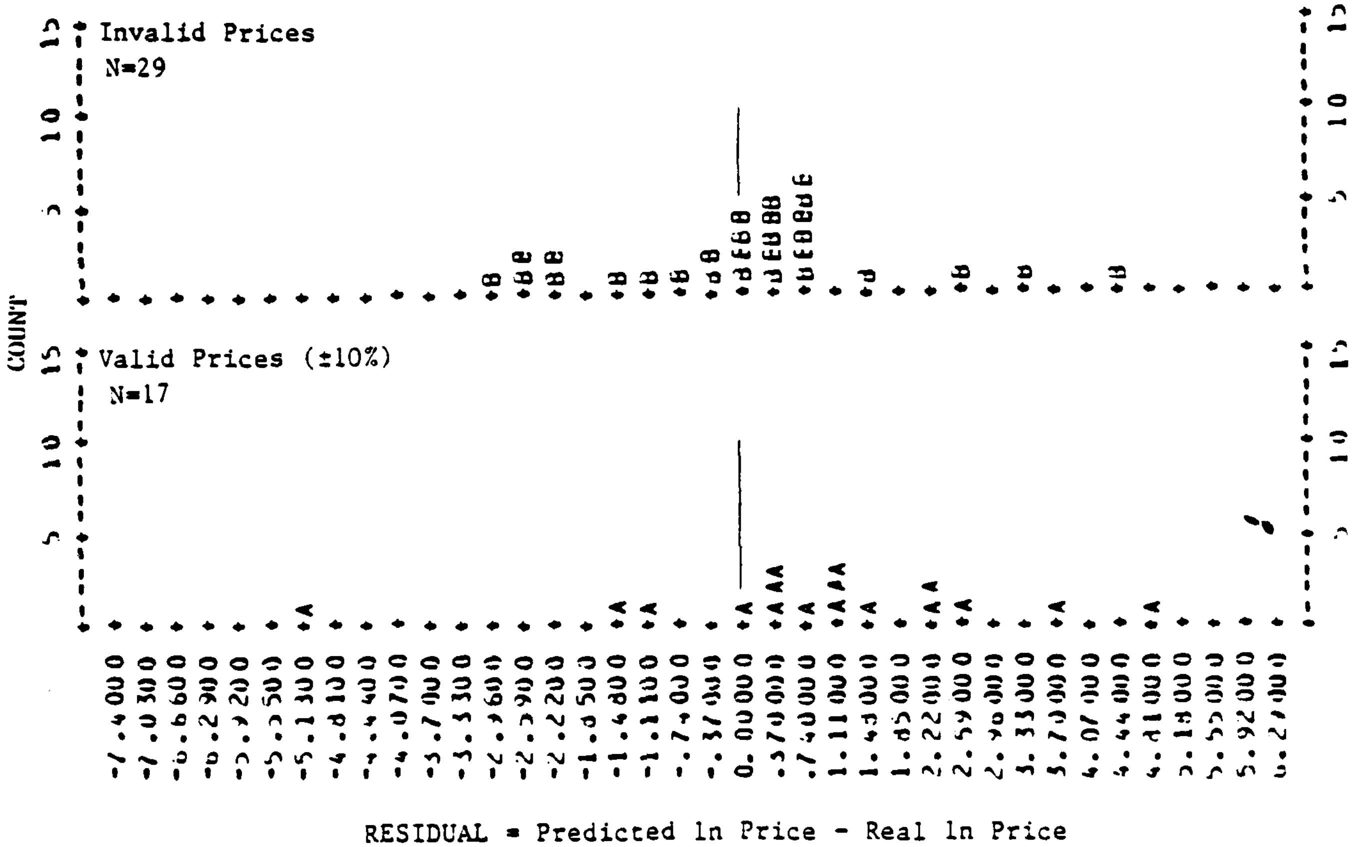


Figure 9. Valid (±10%) & Invalid Residual Density Distributions, FSC 5310

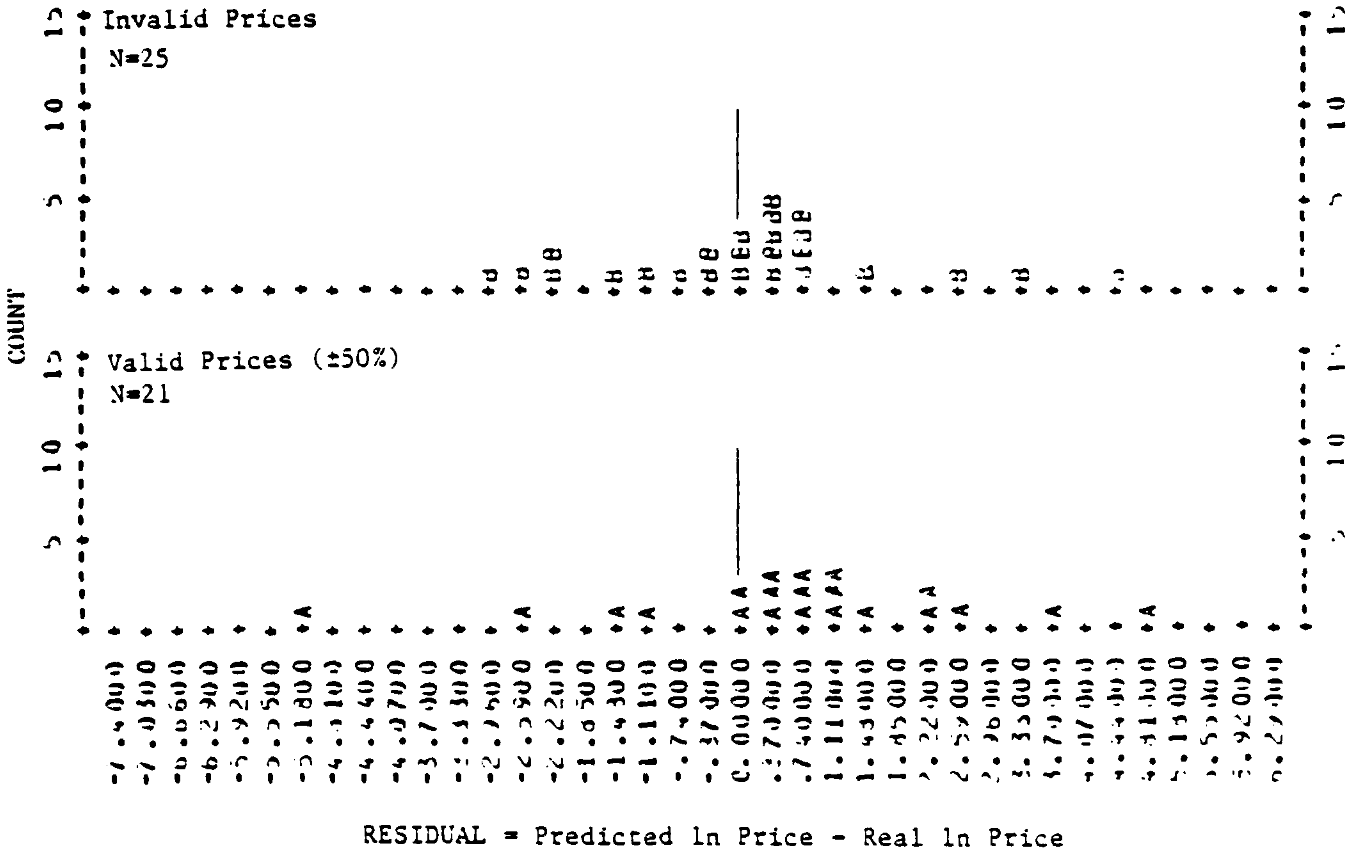


Figure 10. Valid (±50%) & Invalid Residual Density Distributions, FSC 5310

TABLE 9. Comparison of Random Sampling to Optimum Price Bands

FSC	CONTROL GRP SIZE	VALID PRICE CRITERIA	PERCENTAGE OF INVALID PRICES FLAGGED		OPTIMUM PRICE BAND	IMPROVEMENT OVER RANDOM SAMPLING
			RANDOM SAMPLING	OPTIMUM PRICE BAND		
1680	151	± 10%	56	63	45% Top	+ 13%
		± 50%	26	35	75% Two-Sided*	+ 35%
3110	32	± 10%	45	56	40% Top	+ 24%
		± 50%	33	44	40% Top	+ 33%
5310	46	± 10%	63	81	45% Top	+ 29%
		± 50%	54	71	45% Top	+ 31%

*The 45% top band captured 22 invalid prices of 83 flagged (27 percent) for only a one percent improvement over random sampling.

Chapter 7. EXAMINATION OF NOMENCLATURE GROUPS

1. Approach. The approach for nomenclature groups was much the same as that for FSC's. It was attempted to fit functions described by Price = F(Cube, PLT) to the data, and to determine whether or not the control set items whose prices were far from those predicted by the functions were the same items that required price changes during the AMDF Price Scrub.

2. Methodology. The first step was to divide the items with a given nomenclature into sub-groups on the basis of their unit cube. For example, a sub-group might contain all the angle brackets with unit cube between .002 and .004 cubic feet. Next, least-squares straight lines were plotted for each sub-group, with one line through the origin using the form Price = A x PLT, and one general line using the form Price = A x PLT + B. The lines of the second form showed no discernible pattern with increasing cube, so only the lines through the origin were considered further. The next step was to examine the behavior of the coefficient A in the function described by Price = A x PLT, from one unit cube sub-group to another. In the case of Brackets, the coefficient remained about the same for the smaller items, and then increased. For this reason, we hypothesized a prediction function for Brackets of the form:

$$\text{Price} = \text{A1} \times \text{PLT} \times e^{(\text{B1} \times \text{Cube})}.$$

Initial values for A1 and B1, estimated by plotting variables A versus cube, were input to a Non-Linear Least Squares algorithm. This algorithm generated the surface of the above form that minimized the sum of the squares of the residuals for the Bracket price data. Three-dimensional plots of the function and the data showed that the function was not in fact a very good fit. The

last step was to plot the residuals,

$$\log_{10}(\text{Price}) - \log_{10}(F(\text{Cube},\text{PLT}),$$

using different plotting symbols for items whose prices were changed in the price scrub by less than 10%, by between 10% and 50%, and by more than 50%. If deviation from the prediction function was a good indicator of the likelihood that an item needed price scrubbing, then the symbols for unscrubbed items would appear clustered near zero, those for items scrubbed between 10% and 50% somewhat more widely scattered, and those for items scrubbed more than 50% would be far from zero.

3. Results. The three symbols were scattered uniformly over the range of residuals. This can be seen in Figure 11, where the crosses represent items scrubbed less than 10%, the diamonds represent items scrubbed between 10% and 50%, and the circles represent items scrubbed more than 50%. The results were the same for the sub-group consisting of angle brackets. For the bearings and microcircuits, work proceeded only as far as fitting lines to Price versus PLT for the various unit cube sub-groups: the linear coefficients showed no coherent variation with increasing unit cube, so it was impossible to postulate a prediction-function form to feed to the Non-Linear Least Squares algorithm. Working with weight instead of cube gave no better results, as exemplified by Figure 12, where the crosses represent brackets, the triangles represent bearings, and the circles represent microcircuits. The figure shows a large number of microcircuits, having production lead times between 50 and 99 hours, with exactly the same weight (2.85 lbs.), and yet with prices from $5 to $35. For such items, more parameters than cube, weight and PLT need to be available before any prediction function can be developed.

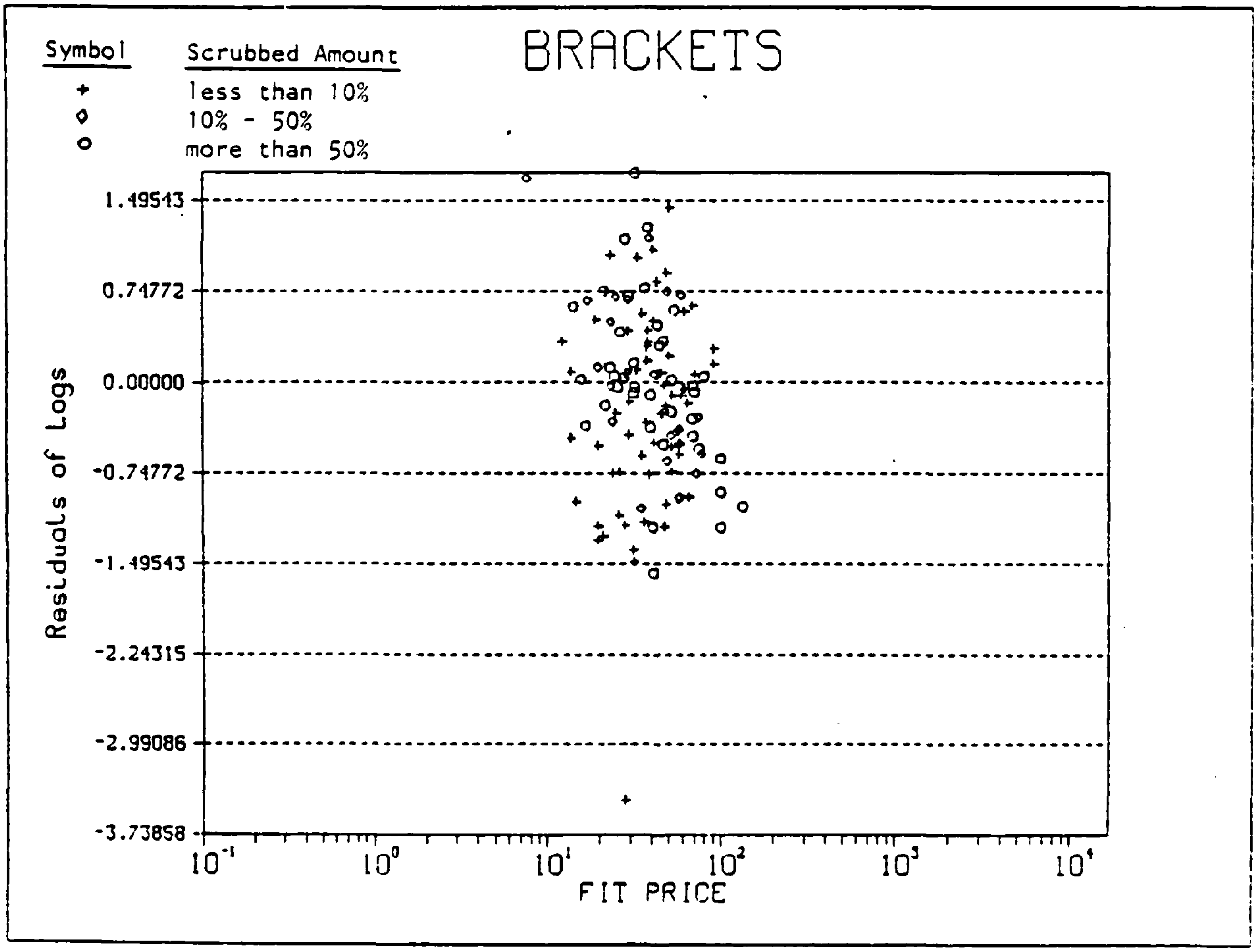


Figure 11. Residual Plot of Brackets Control Group

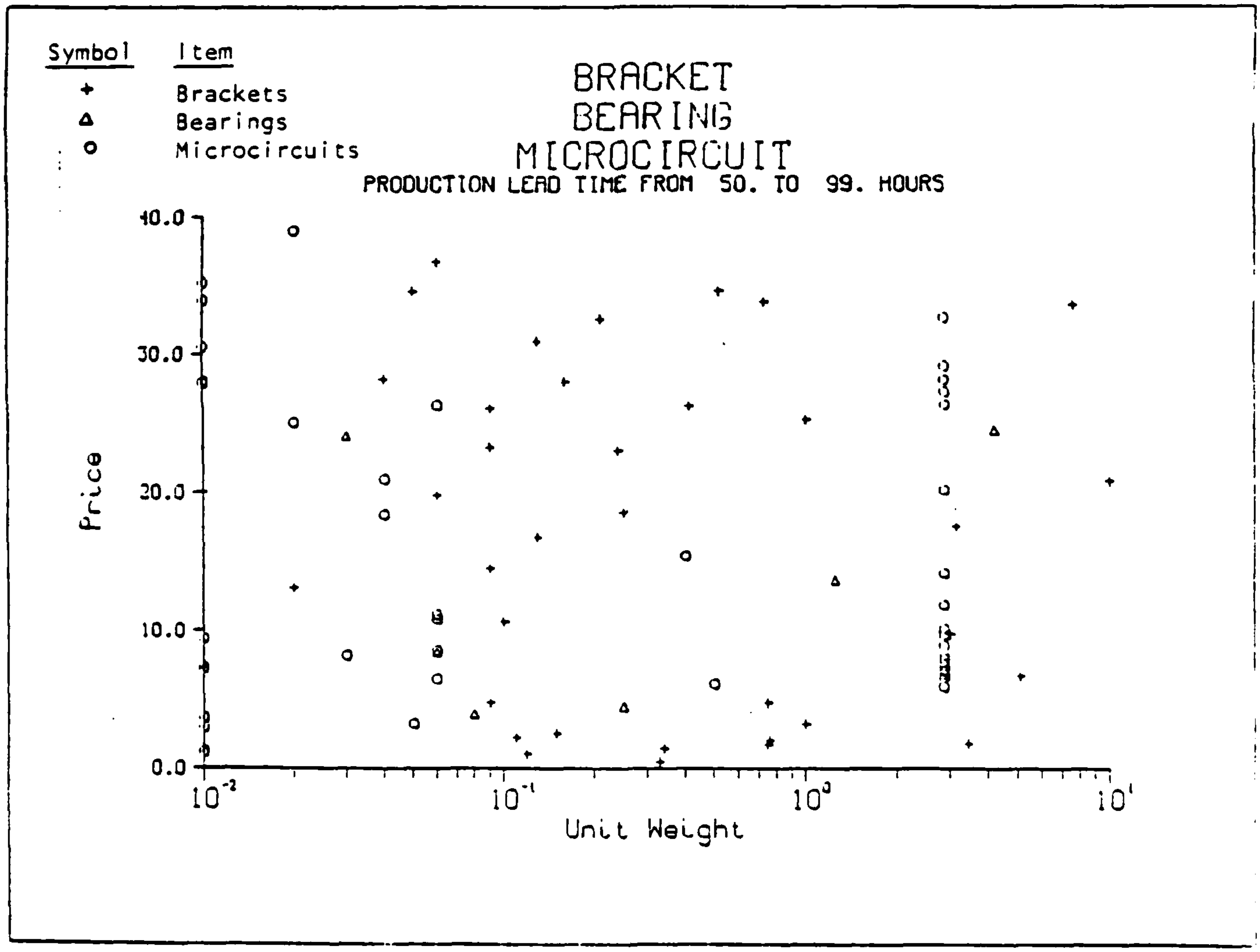


Figure 12. Price Versus Unit Weight for Brackets, Bearings, and Microcircuits

Chapter 8. FINDINGS AND CONCLUSIONS

1. For price bands to be effective in segregating invalid from valid prices, item parameters must exist that produce a high correlation to valid prices and low correlation to invalid prices. High correlation between price and the item parameter(s) for all items is not satisfactory since the invalid prices lie on or about the regression line (or surface) and, therefore, could not be flagged by price bands placed around the regression line (or surface). No parameters were found that could segregate invalid from valid prices.

2. The parameters chosen for the three analyzed FSC groups; i.e., ln price versus PLT and ln cube, resulted in poor correlation. Most of the invalid prices in the control data (the previously scrubbed prices) had high prices which had to be reduced, such that using one-sided bands placed above the regression surface captured more invalid prices than expected from random sampling. The large quantity of high priced invalid prices indicates that similar results could be obtained by just flagging those prices which were above a price limit set somewhere above the mean ln price for the FSC group.

3. A review of relatively high priced items reveals extremely invalid prices. A 33 and 31 percent improvement over random sampling in finding items whose prices were incorrect by more than 50 percent was found for FSC groups 3110, Bearings, Antifriction Unmounted, and 5310, Nuts and Washers, respectively.

4. The nomenclature found in the AMDF for Class IX items is only one parameter to consider, along with cube, weight, and production lead time, in predicting price validity. The 19-character nomenclature does not contain sufficient data on the items to distinguish items within a nomenclature group or sub-group.

5. The results from all the FSC and nomenclature groups examined show that the parameters in computer-readable form available in the AMDF are not sufficient to provide a basis for screening prices.

Chapter 9. RECOMMENDATIONS

1. Correlation and regression analysis used to predict price based on item parameters cannot segregate invalid prices from valid prices. Therefore, it is not a suitable approach for developing price bands.
2. At the present technology level of artificial-intelligence, it is not a practical approach to a price screening procedure. As the field of artificial-intelligence matures, its application should be reinvestigated. However, an artificial-intelligence approach would require more detailed data than is presently available in the cataloging system.
3. Further research is needed in the area of price limits as a price screening tool. Price limits should be analytically determined from a methodology that is simple to apply.

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APPENDIX A

FREQUENCY HISTOGRAM OF REVISED PRICE/ORIGINAL PRICE RATIOS

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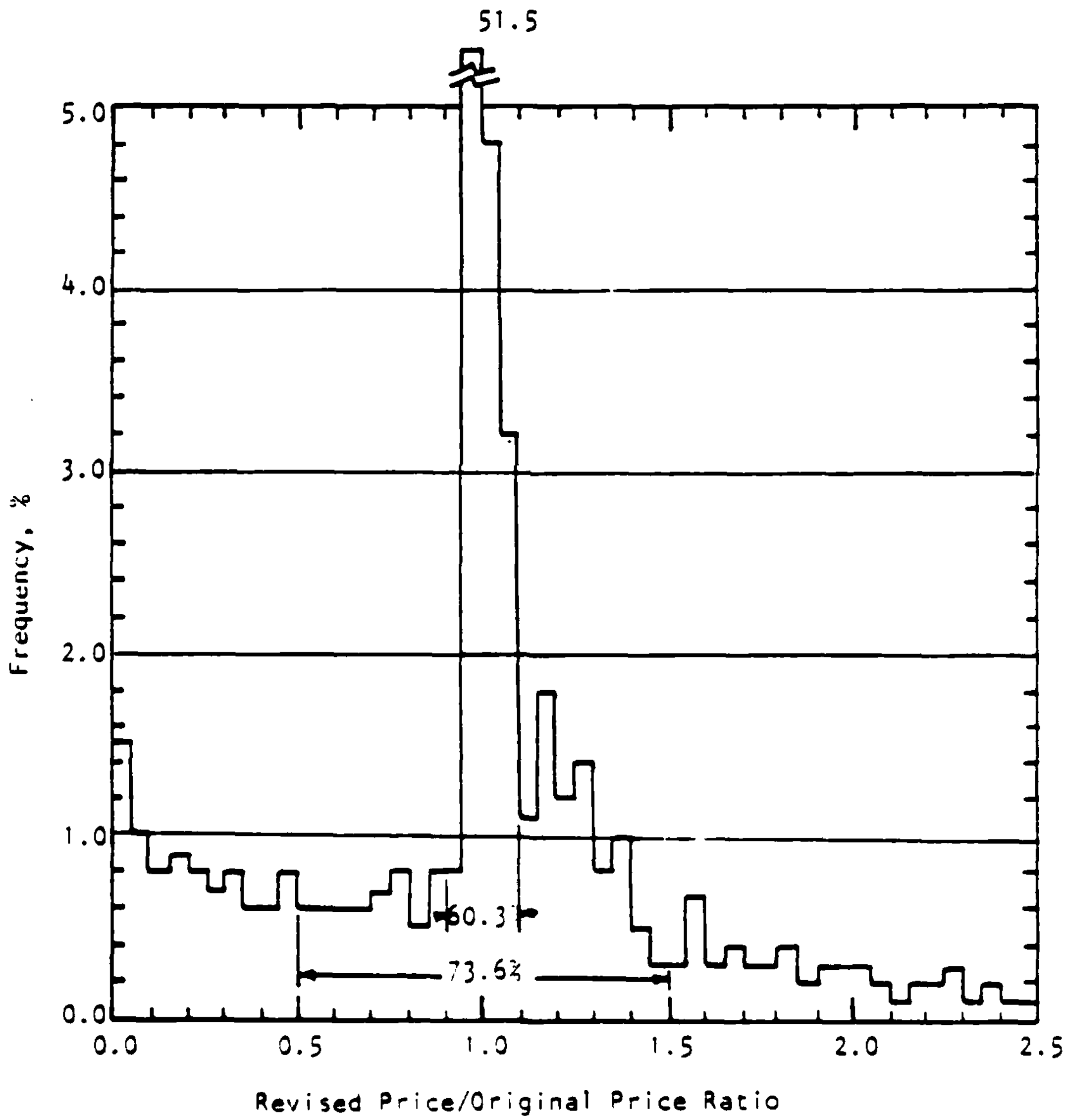
Frequency Histogram
of
Revised Price/Original Price Ratios



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APPENDIX B

SCATTER PLOTS OF PRICE vs ITEM PARAMETERS

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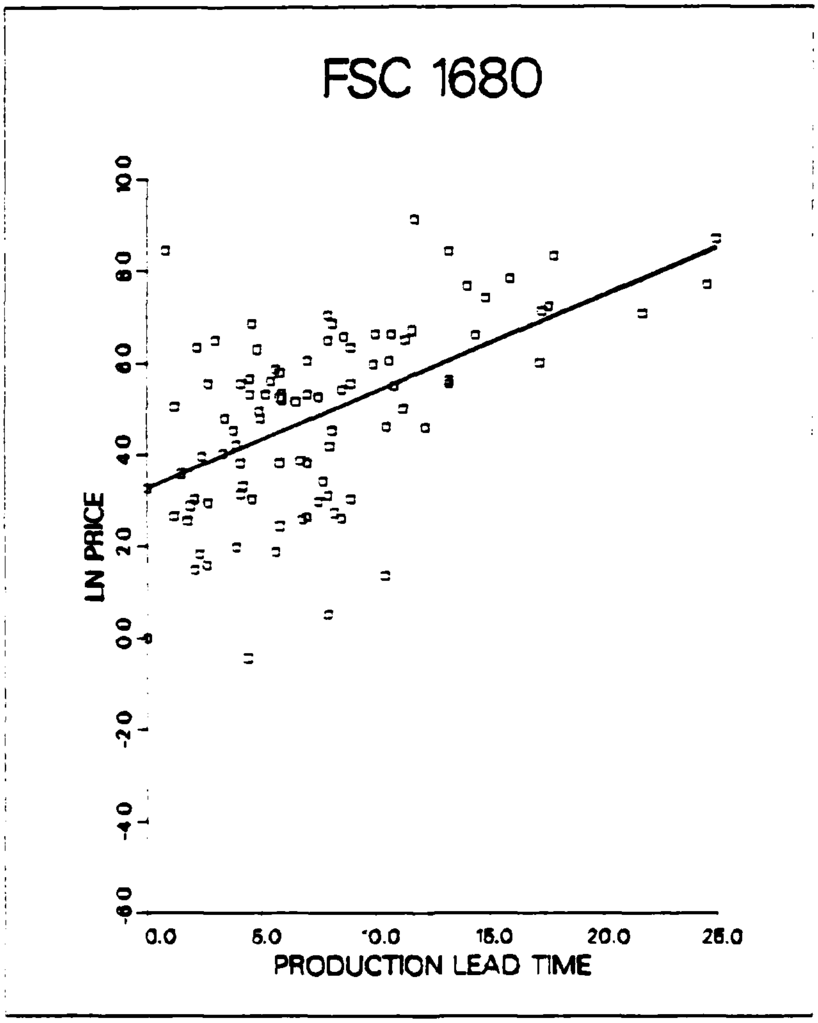
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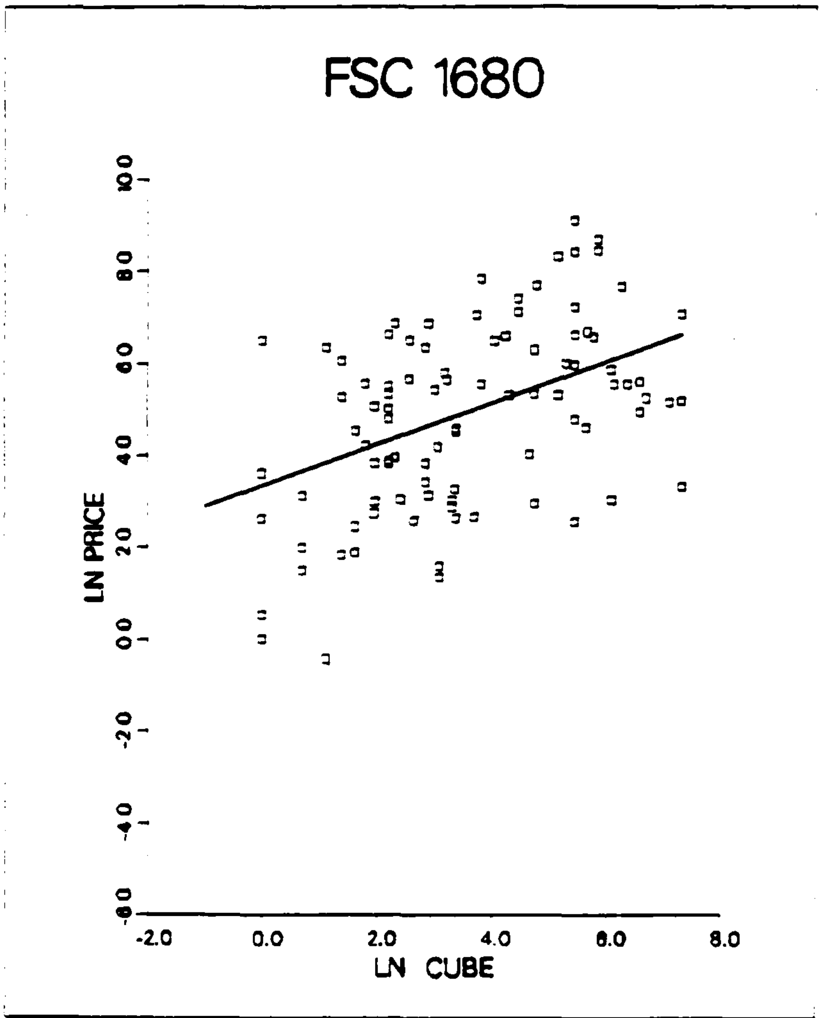
LN PRICE
PRODUCTION LEAD TIME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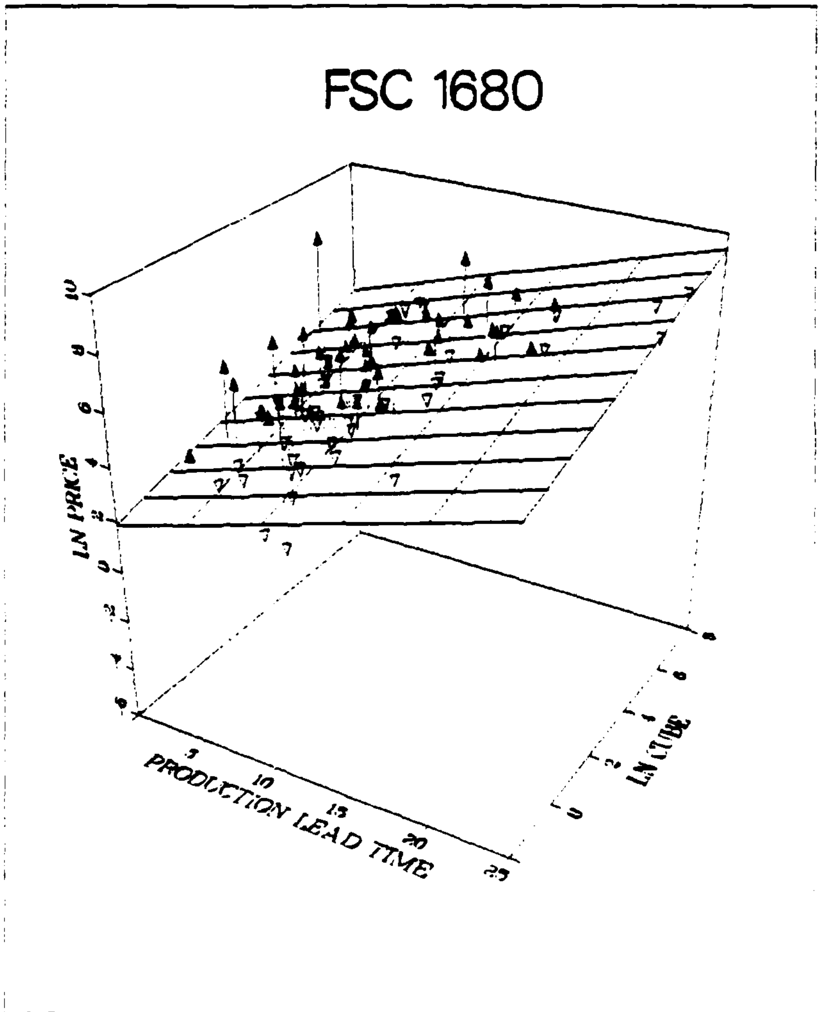
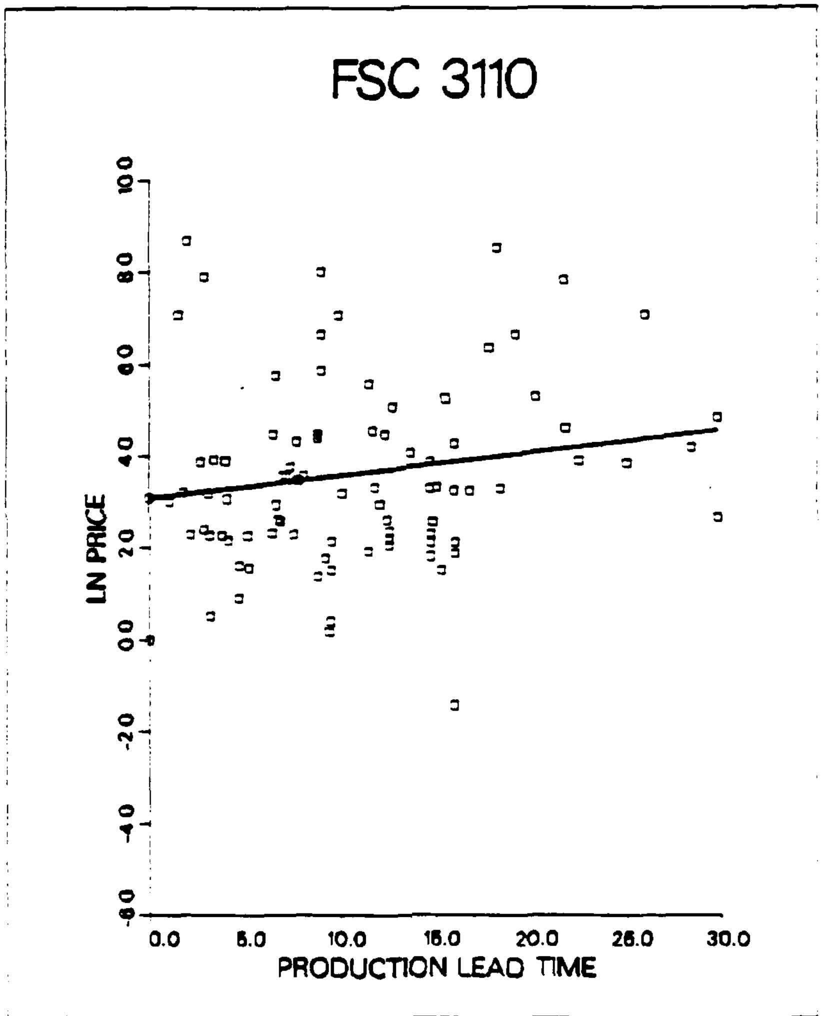
LN PRICE
LN CUBE



FSC 1680
LN PRICE
PRODUCTION LEAD TIME
LN CUBE


FSC 3110
LN PRICE
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
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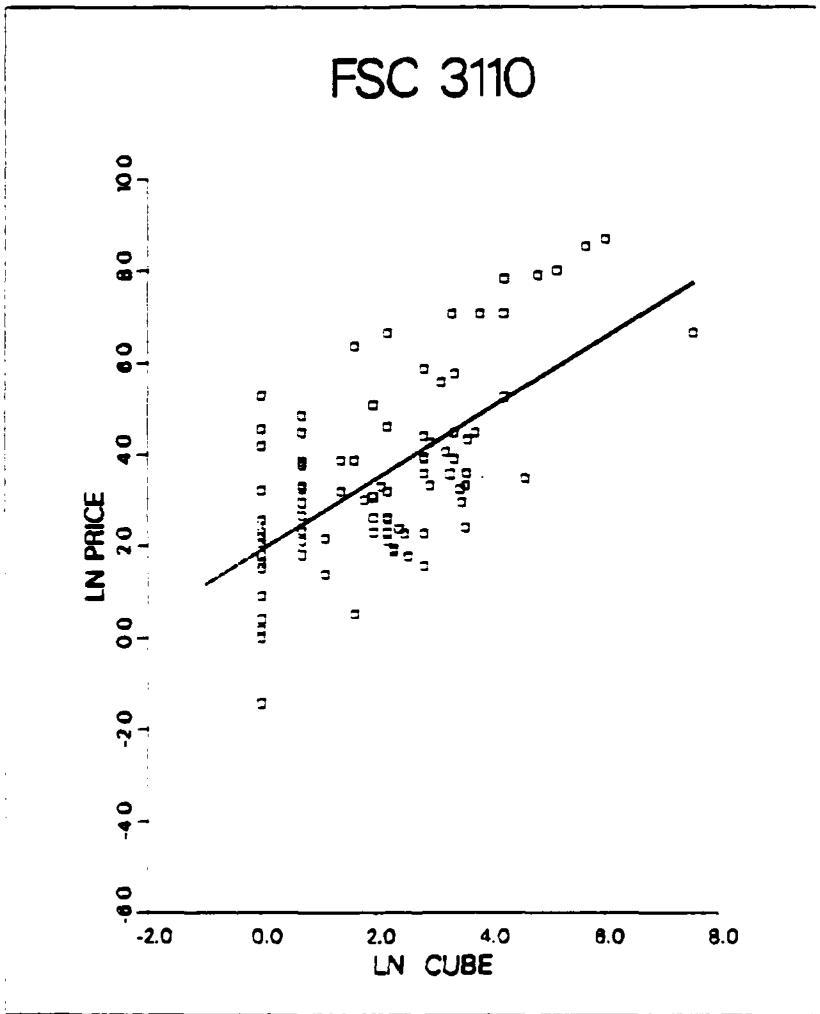
-6.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
PRODUCTION LEAD TIME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LN CUBE
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2.0
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0.0
2.0
4.0
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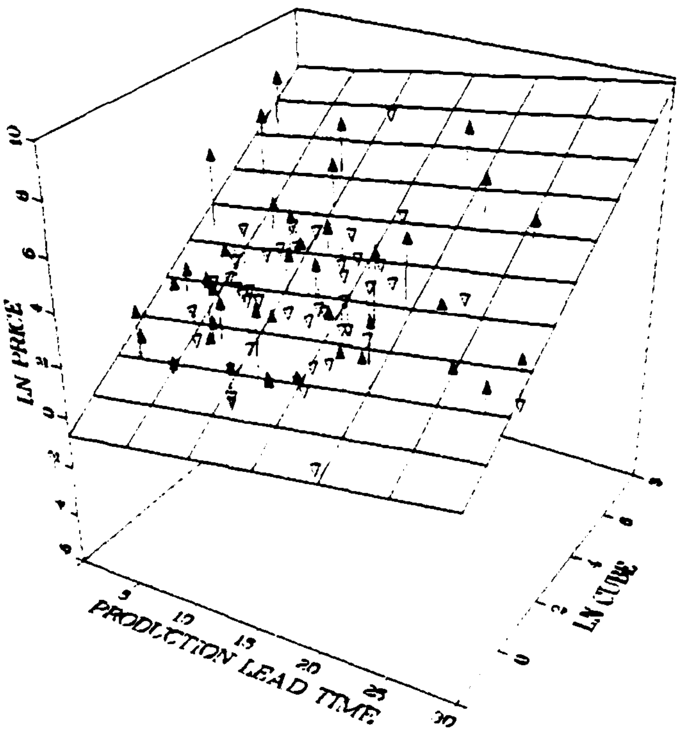
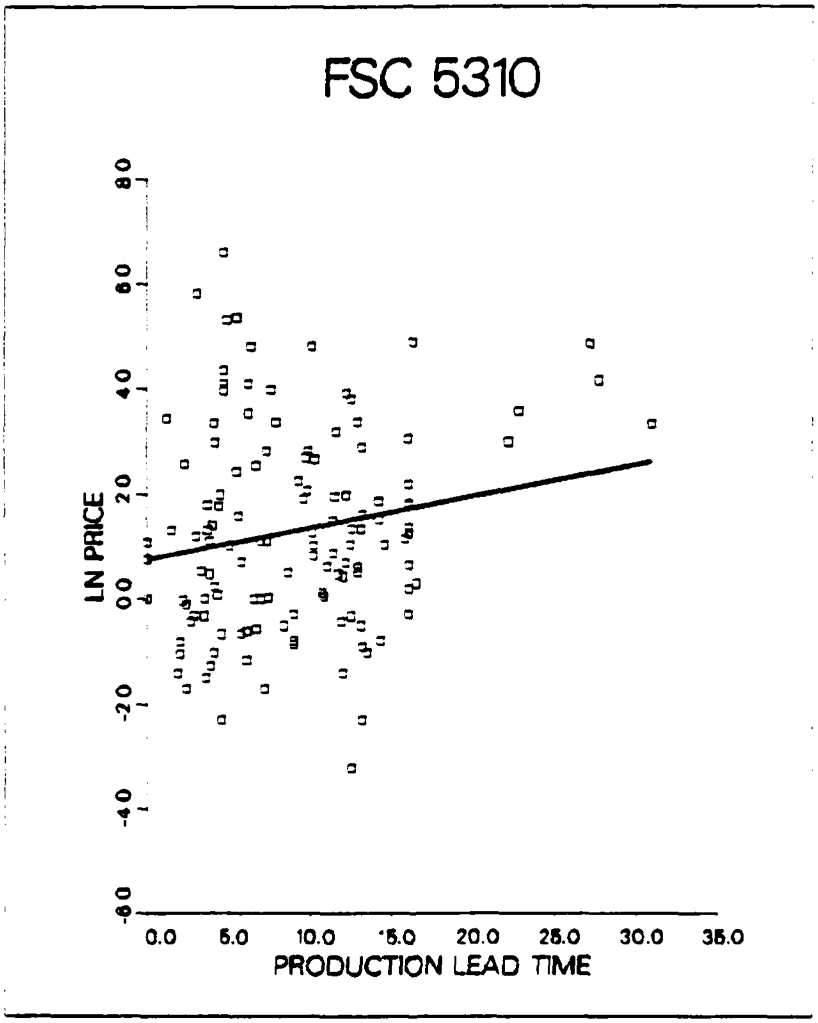
8.0

FSC 3110




FSC 5310
LN PRICE
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60
40
20
00
-20
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-60
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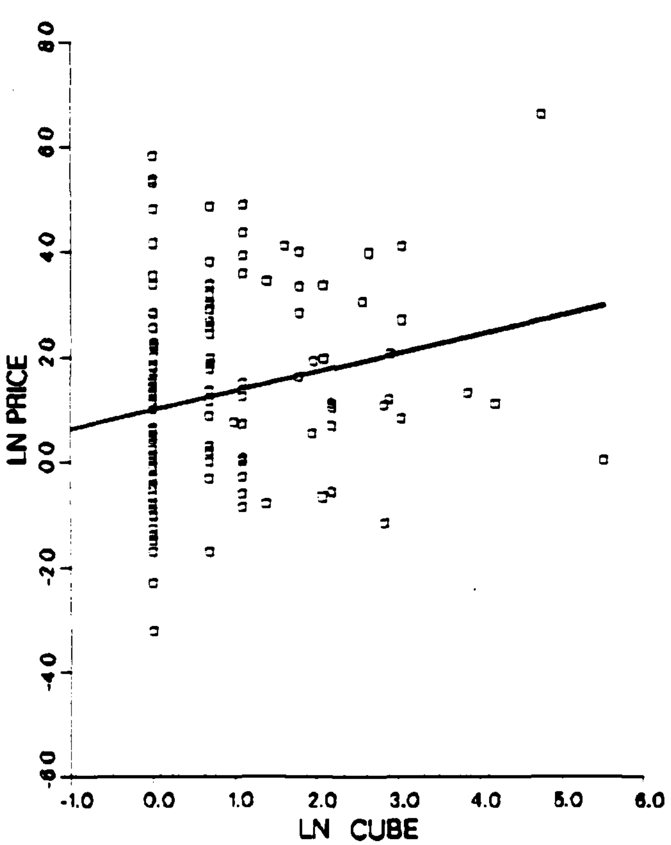
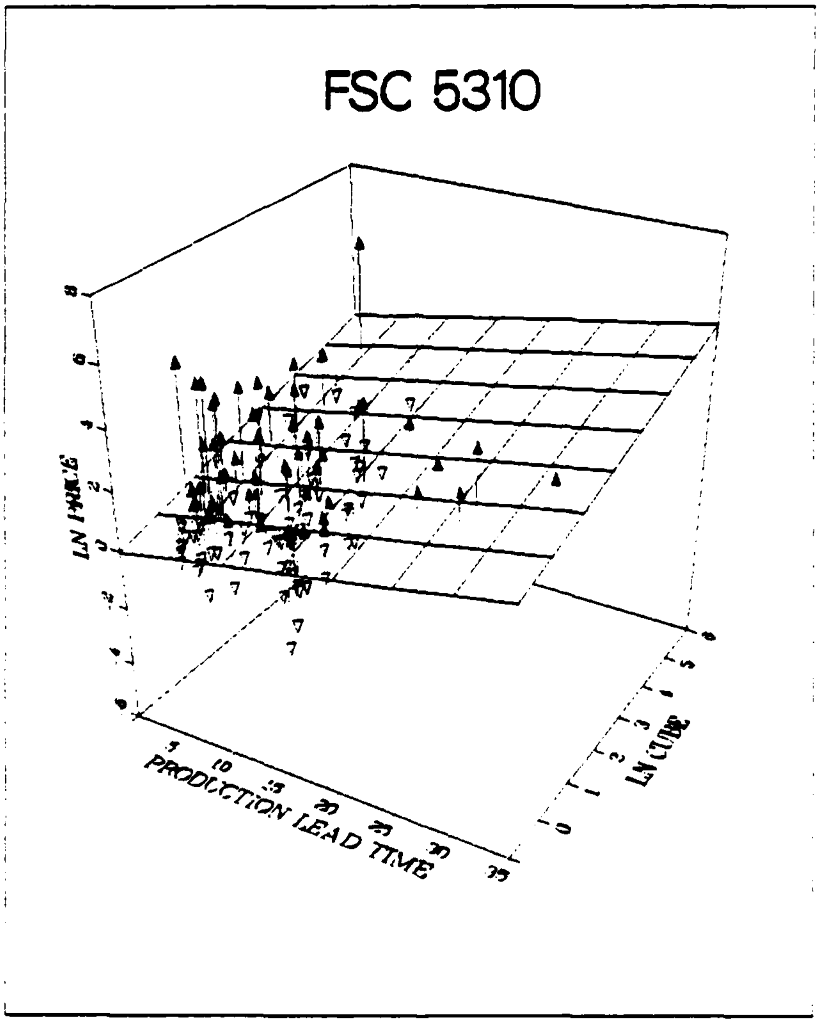
5.0
10.0
15.0
20.0
25.0
30.0
35.0
PRODUCTION LEAD TIME

FSC 5310




FSC 5310
LN PRICE
PRODUCTION LEAD TIME
LN CUBE

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APPENDIX C

EXPERT SYSTEM APPROACH

As a supplement to this study, the feasibility of using artificial-intelligence to develop pricing screens was investigated. Following is a summary of the findings.

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1. The FY 84 Data Scrub of the Army Master Data File (AMDF) was conducted by engineers at the AMC major subordinate commands. There aren't enough engineers to scrutinize the prices for all items purchased. If their expertise could be captured in a computer program, that program could flag items whose prices seem invalid. The feasibility of such a computer program was investigated by interviewing production engineers at AMCCOM's Production Directorate to find out how they scrub prices.

2. The engineers decide which parts to review according to a priority scheme. Then, each selected item is examined to determine if its price is accurate.

a. All items whose prices exceed a certain dollar level are reviewed, regardless of procurement history and method of procurement. This level is around $100,000. Because the cost engineering group within the Production Directorate consists of only eight engineers, inexpensive items scheduled for low-volume purchase are not scrutinized. For medium-priced items, method of procurement and past history are considered. Those items which have been purchased competitively, with several confirmed contracts within the preceding two years, are not scrubbed. It is assumed that their prices accurately reflect the market. This assumption may be questioned because of the way fixed costs are allocated by a contractor to Government-procured items of varying prices within the same contract. If the contractor allocates an equal percentage of these costs to each item, those low-cost items which the Government buys in large quantities will include in their prices a fixed-cost allocation in excess of the true share of the overall fixed costs incurred in producing them.

b. Among the remaining items, those procured sole source are most likely to be scrubbed. Next in priority come items bought from only a few sources. Then come items bought competitively, but not within the preceding two years.

c. In scrubbing the price, the engineer starts with the Logistics Support Analysis Record (LSAR), with its diagrams and accompanying text. There are three types of subcomponents that the item may contain:

(1) One type is a Military Specification component. AMCCOM has a computer file of all the Mil Spec items it has examined, with their associated prices. The engineer checks the contractor's price for such a subcomponent against the computerized file.

(2) The second type of subcomponent is one purchased from a vendor. The engineer first tries to find a catalog from that vendor which lists the price of the subcomponent. Often, catalogs do not show prices, and sometimes there is no catalog. In that case, the engineer telephones the vendor to verify the price. Sometimes, the vendor is closely allied to the prime contractor, inflating the price of an item just because it is to be sold to the Government. The engineer has to judge when this is likely to occur and to telephone a succession of vendors until he finds one who sells the subcomponent on the open market.

(3) The third type of subcomponent is fabricated by the contractor. The engineer follows published guidance (e.g., Electronics Industry Cost Estimating Data Update by DLA or US Army CECOM Cost Estimating Handbook, EH-1), as well as his own experience, in determining whether the price is reasonable and accurate. Experience has shown that some contractors charge more than others for making the same component.

3. An expert system that operates in a batch-processing mode, scanning thousands of parts at once and flagging those whose prices look suspicious, is not feasible given the present data base. Lone-line descriptions of parts usually do not exist within CCSS. Where they do exist, they seldom contain the sort of

information that an articicial-intelligence program could use to derive reasonable costs: materials, labor, and capital requirements. For many parts, weight and cube information are absent. Understanding a diagram with accompanying text is a problem still in basic research at the universities, and is beyond today's state of the art in artificial intelligence. A computer program cannot read telephone vendors or catalogs. Therefore, the approach using a batch-processing expert system was not pursued further in this study.

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GIST

AMSAA	TITLE Price Screening Methodology BRIEFING ____ REPORT X	

THE PRINCIPAL FINDINGS and recommendations of the work reported herein are as follows:

1. Correlation and regression analysis used to predict price based on item parameters cannot segregate invalid prices from valid prices. Therefore, it is not a suitable approach for developing price bands.

2. At the present technology level of artificial-intelligence, it is not a practical approach to a price screening procedure. As the field of artificial-intelligence matures, its application should be reinvestigated. However, an artificial-intelligence approach would require more detailed data than is presently available in the cataloging system.

3. Further research is needed in the area of price limits as a price screening tool. Price limits should be analytically determined from a methodology that is simple to apply.

THE MAIN ASSUMPTIONS

1. Prices scrubbed during the 1984 Army Master Data File (AMDF) Price Scrub are now valid.

2. Production Lead Time is reasonably stable between successive procurements.

PRINCIPAL LIMITATIONS

1. Prices for secondary items are skewed to low values. This makes regression analysis difficult to apply.

2. Many interrelated factors influence price. It is hard to select just a few that accurately predict price.

3. The quantity of pre-scrubbed price data from the AMDF Price Scrub was insufficient to draw strong conclusions about the effectiveness of the price bands in comparison to random sampling.

THE SCOPE OF THE STUDY was limited to Army Stock Fund (ASF) secondary items from three Federal Supply Classification (FSC) classes and three nomenclature categories. Item parameters available in CCSS were used in the analysis.

THE STUDY OBJECTIVE

Determine the feasibility of developing pricing screens to flag invalid unit prices.

THE BASIC APPROACH

Correlation analysis was used to select item parameters with the best correlation to price. Price limits placed around the best fit regression surface represented the price bands. Previously price scrubbed items comprised a control group. The control group was screened by the bands to determine the effectiveness of the bands to flag invalid prices. The location of the bands were optimized based on the highest percentage of invalid prices found of the total number flagged. These results were compared to the expected outcome from random sampling, which is based on the underlying portion of invalid prices in the control group.

THE REASONS FOR PERFORMING THE STUDY

Unit price estimates for spares of new systems entering the Army inventory are often inaccurate. These price estimates are entered into the AMDF as the Army's standard price used for budgeting and requisitioning. A system is needed to flag suspect prices for validation prior to entering the AMDF.

STUDY IMPACT STATEMENT

If a price limit methodology can be developed to accurately screen prices, it will help eliminate the outrageous overpriced cases which eventually come under Congressional scrutiny.

THE STUDY SPONSOR was the US Army Materiel Command (Office of the Deputy Chief of Staff for Supply, Maintenance, and Transportation).

ADDRESS FOR COMMENTS AND QUESTIONS. Director, AMSAA, ATTN: AMXSY-LLSO (Edward F. Glavan), Fort Lee, Virginia 23801-6046.

DTIC/DLSIE ACCESSION NUMBER OF FINAL REPORT. DA 307269.

GIST

	TITLE	
AMSAA	Price Screening Methodology	
	BRIEFING ____ REPORT X	

THE PRINCIPAL FINDINGS and recommendations of the work reported herein are as follows:

1. Correlation and regression analysis used to predict price based on item parameters cannot segregate invalid prices from valid prices. Therefore, it is not a suitable approach for developing price bands.

2. At the present technology level of artificial-intelligence, it is not a practical approach to a price screening procedure. As the field of artificial-intelligence matures, its application should be reinvestigated. However, an artificial-intelligence approach would require more detailed data than is presently available in the cataloging system.

3. Further research is needed in the area of price limits as a price screening tool. Price limits should be analytically determined from a methodology that is simple to apply.

THE MAIN ASSUMPTIONS

1. Prices scrubbed during the 1984 Army Master Data File (AMDF) Price Scrub are now valid.

2. Production Lead Time is reasonably stable between successive procurements.

PRINCIPAL LIMITATIONS

1. Prices for secondary items are skewed to low values. This makes regression analysis difficult to apply.

2. Many interrelated factors influence price. It is hard to select just a few that accurately predict price.

3. The quantity of pre-scrubbed price data from the AMDF Price Scrub was insufficient to draw strong conclusions about the effectiveness of the price bands in comparison to random sampling.

THE SCOPE OF THE STUDY was limited to Army Stock Fund (ASF) secondary items from three Federal Supply Classification (FSC) classes and three nomenclature categories. Item parameters available in CCSS were used in the analysis.

THE STUDY OBJECTIVE

Determine the feasibility of developing pricing screens to flag invalid unit prices.

AMSAA Form 43R (18 Jul 85)
Previous editions of this form are obsolete.

THE BASIC APPROACH

Correlation analysis was used to select item parameters with the best correlation to price. Price limits placed around the best fit regression surface represented the price bands. Previously price scrubbed items comprised a control group. The control group was screened by the bands to determine the effectiveness of the bands to flag invalid prices. The location of the bands were optimized based on the highest percentage of invalid prices found of the total number flagged. These results were compared to the expected outcome from random sampling, which is based on the underlying portion of invalid prices in the control group.

THE REASONS FOR PERFORMING THE STUDY

Unit price estimates for spares of new systems entering the Army inventory are often inaccurate. These price estimates are entered into the AMDF as the Army's standard price used for budgeting and requisitioning. A system is needed to flag suspect prices for validation prior to entering the AMDF.

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